Technology on Reducing Post-harvest Losses and Maintaining Quality of Fruits and Vegetables

Proceedings of 2010 AARDO Workshop

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Preface

Fruits and vegetables are vital for a healthy diet. Both are low in energy and packed with fibers, viltamins, minerals and a lot of beneficial phytochemicals. Due to their nutritional and health benefits, fruit and vegetables are recommended to form the basis of our daily dietry. Studies further suggest that fruit and vegetables should be incorporated into every meal, with a minimum intake of five protions each day.

The perishable nature of fruit and vegetables prompts them to easily deterioration during postharvest processing and storage, even though with high production at harvest. Losses range from 10 to 50%, depending on the commodities, seasons, areas, availability of infrastructures, awareness of the proper handling and the way of processing. Deterioration becomes even more severe when temperature rises and transport facilities are problematic. The use of improved postharvest technologies could help in maintaining the good quality of fruit and vegetables and reducing the safety risks of customers. It is in this regard that Afro-Asian Rural Development Organization (AARDO) brought togther with the Council of Agriculture (COA), Taiwan, Republic of China to organize this international workshop and held at Taiwan Agricultural Research Institute (TARI) in 3-9 October 2010.

The workshop provided a venue for researchers, specialists and related personnels of AARDO member countries to exchange knowledge, experiences and technologies that may lead to the formulation of appropriate policies and feasible action plans fitted to specific demand in different countries. By reviewing and discussing the achievements and constraits in the applications of postharvest technologies, the workshop also served as a forum where participants of member countries of AARDO can share and diffuse information among themselves to the benefits of farmers and industrial development for their home land. Moreover, a number of topics of postharvest biology and technology were conveyed through the lectures by the resource speakers in aid of the participants an in-depth understanding of the underlying mechanisms behind the use of the introduced techniques and technologies.

The postharvest handling situation and the used technologies of each participating country have been presented by the participants in their country reports. Each presentation was open to discussion, suggestions and comments, and therefore, presenter can have a fruitful feedback from a multifacet perspective and different views and ideas. A field trip of selective cold storage facilities and the wholesale market have also been arranged so that the participants become more aware of the available postharvest strategies that could be adopted as well as adapted in their own countries. Further, three aspects of “Challenges and Opportunities in the Improvement on Postharvest Handling Technologies to Reduce Losses and Maintain Quality of Fruits and Vegetables”, “Priorities and Strategies in Overcoming the Challenges in the Development of Postharvest

Technologies", and "Priorities and Strategies in Future Research, Development and Application of Postharvest Technologies" have been assigned for group discussion, through which the participants of each group concluded their grouped action plans based on their specific conditions and situations, and resulted into useful recommendations for other group members to be adapted for different slots.

This report wraps up all the results of the efforts of resource speakers, participants, and the staff of TARI. I hope that the information provided would initiate more advanced thoughts that are useful for problem solutions encountered in postharvest processing in the future. Allow me also to take this opportunity to extend my sincere thanks to all those who contributed to make this workshop successful.

Junne-Jih Chen, Ph.D.

Junne-Jih Chen

Director General,

Taiwan Agricultural Research Institute

December 2010

Opening Ceremony

Opening Remarks

Dr. Junne-Jih Chen

Director General

Taiwan Agricultural Research Institute

Mr. Sanjeeb Kumar Behera, Head of Research Division of Afro-Asian Rural Development Organization, Distinguished Speakers, Dear Participants, Ladies and Gentlemen:

Good morning!

On behalf of the Council of Agriculture of Taiwan, I sincerely welcome all of you to attend the opening ceremony of 2010 AARDO Workshop on Technology on Reducing Post-harvest Losses and Maintaining Quality of Fruits and Vegetables. As the Director General of Taiwan Agricultural Research Institute, I would also like to express my warmest welcome to every one of you, especially those speakers and participants flying a long way to this country, for coming to this important and meaningful workshop.

AARDO has been playing a very important role, with remarkable outcomes, in promoting agricultural development in African and Asian countries. The Council of Agriculture of Taiwan is proud of having a long history of collaboration with AARDO in upgrading the agricultural production technology for farmers in these regions. We are happy to have the opportunity to move one step forward by hosting this workshop here at TARI. TARI looks forward to having more of such cooperation with AARDO and other international organizations in order to benefit farmers in need of usable and practical technologies to enhance both quantity and quality of their farm produces.

My thankfulness also extended to the respected resource speakers for accepting our invitation to share with us their invaluable expertise and experiences. Thank you for your generosity and full support. I have no doubt at all that by attending this workshop, all the participants will be much better equipped and prepared in post-harvest technology to assist your local farmers.

As we know, most fruits and vegetables are highly perishable and subject to decay or spoil, especially for those produced in tropical and subtropical areas like Taiwan and your countries. Post-harvest technology is very important not only in reducing post-harvest losses, but also in maintaining high quality of the produces. On the other hand, storage technique is equally

important for off season supply. By such a way, the demand and supply may be balanced and higher values of products can be sustained. Many kinds of fruits and vegetables can therefore be exported to those countries where tropical and subtropical products are rare. In fact, these kinds of exportation also reduce the pressure from over production problem.

In addition to postharvest technology, other issues of postharvest management, such as value adding, energy saving, and cost reduction will be included in the lectures. In regard to food safety, how to minimize pesticide residues in the produce is another important issue to be concerned. Our resource speakers will provide the most useful information dealing with these subjects.

Moreover, a few places have been arranged for the participants to visit in the field trip. You will have opportunities to overview the operations of post-harvest handling in the industrial plants which must be of practical value for your future work.

Should you have any opinions, suggestions or comments for the bettering of the workshop during the sessions, please do not hesitate to let us know. TARI's staff will do their best to provide you a very safe, pleasant, and fruitful stay in Taiwan.

Finally, I would also like to take this opportunity to express my gratitude to the staff members of TARI. for their hard working and excellent performance in preparing this workshop during last few months, especially to Dr. Ou and Dr. Huang of the Division of Crop Science.

Thank you.

Welcome Address

Dr. Sanjeeb Kumar Behera

Head of Research Division
Afro-Asian Rural Development Organization

Respected Dr. Junne-Jih Chen, Director General, Taiwan Agricultural Research Institute, Distinguished Resource Persons, Participants from AARDO Member Countries, Learned Faculty Members of TARI, Coordinator of This Programme Dr. Chao-Chia Huang, Ladies and Gentlemen:

I am addressing this august gathering in the absence of my Secretary General H.E. Dr. Abdalla Yahia Adam, who could not come here due to his other important assignment in connection to the Executive Committee meeting of the Organization. In his absence, I have the privilege to welcome you all to this international Workshop on “Technology on Reducing Post-harvest Losses and Maintaining Quality of Fruits and Vegetables”, being organized by Afro-Asian Rural Development Organization (AARDO) in collaboration with the Council of Agriculture (COA), Executive Yuan and Taiwan Agricultural Research Institute (TARI), Taichung.

At the outset, I wish to convey my sincere thanks to the esteemed Government of the Republic of China for the kind support and unceasing cooperation in hosting this important international workshop in this beautiful campus of TARI.

Ladies and Gentlemen, Republic of China has always been in the forefront in AARDO’s endeavour to increase the number of inter-governmental collaborations in the sphere of rural development - not in terms of Human Resource Development programme alone, but also in financing development pilot projects in member countries and contributing to the AARDO Development Fund. I do not want to go into the details of those supports, but wish to mention here that Republic of China provides fully paid fellowships to the participants from AARDO member countries in different training programmes in its centres of excellence. These training programmes provide good exposure to the participants on the developmental practices followed in the Republic of China. During the current year, AARDO Secretariat has received as many as 46 nominations from AARDO member countries for the 9 available slots for training programmes covered under ICDF. Besides, AARDO has also four training slots for the land reforms training programme. These training programmes in this country have definitely brought Republic of China more close to other AARDO member countries in the recent past as evident from the growing demand for these courses. The country is also giving a space for the senior officials of AARDO member countries to study and observe the technological advancements made in Republic of China under

its “Study Visit Programme” in the field of agricultural and rural development. I sincerely hope that the same support of R.O. China to AARDO and its member countries will continue in the future also.

Ladies and Gentlemen, allow me to say few words about AARDO, which is one of the earliest examples of South-South Cooperation and Afro-Asian solidarity. Established in 1962, AARDO is an international, intergovernmental Organization in the field of agricultural and rural development. AARDO’s membership strength presently stands at thirty – fifteen from Africa, fourteen from Asia as full members and one associate member from Africa. AARDO Secretariat is based in New Delhi and is assisted by five regional offices in the implementation of its technical work programme. The five regional offices of AARDO are located at Seoul, Republic of Korea for the Far East; Amman, Hashemite Kingdom of Jordan for Middle East; Accra, Republic of Ghana for West Africa; Cairo, Arab Republic of Egypt for North and Eastern Africa; and Lusaka, Republic of Zambia for Southern Africa. AARDO enjoys Observer status with various UN and other international/regional organizations like Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Conference on Trade and Development (UNCTAD), United Nations Educational, Scientific and Cultural Organization (UNESCO), International Cooperative Alliance (ICA), etc.

With regard to the functions of AARDO, I would like to mention here that the Organization acts as a catalyst and provides a forum for the member countries in the Afro-Asian region to jointly discuss their problems, exchange views, ideas, experiences and information in the field of rural and agricultural development, pool their resources, and make concerted efforts, wherever possible, to improve the quality of life of their rural people. AARDO’s strategies for rural development focus on three broad areas: i) human resource development through training programmes, workshops/seminar, study visits, etc.; ii) financing of development pilot projects addressing social and economic issues as well as transfer of technology; and iii) dissemination of information.

Ladies and Gentlemen, I must express my gratitude to the distinguished resource persons for their participation in the workshop. I am sure their vast knowledge, experience and expertise on the subject will enrich the deliberations and help in arriving at concrete recommendations. I further wish to thank the distinguished participants from AARDO member countries for enduring the long-distance traveling to come to Taiwan to share their country’s experience and make the workshop more meaningful.

I would have failed in my duty had I not taken the opportunity to thank the Organising Committee for the excellent arrangements made in organising this workshop. Thanks are due to Dr. Junne-Jih Chen, the Director General of TARI and his team for hosting the workshop here in TARI.

We have, among us, distinguished participants and resource persons from 11 AARDO member countries of People's Republic of Bangladesh, Republic of Gambia, Republic of India, Hashemite Kingdom of Jordan, Republic of Kenya, Republic of Mauritius, Sultanate of Oman, Republic of the Philippines, Republic of the Sudan, Republic of Zambia and the host country, Republic of China to share their knowledge, experiences and ideas.

On behalf of my Organization and my Secretary General, I wish all the participants a fruitful deliberation and rewarding experience. I thank all the dignitaries for their gracious presence. I also, once again, take this opportunity to thank the organizers for the excellent arrangements and wish all the participants a memorable stay in this island country.

Thank you for you kind attention.

Resource Papers

2010 AARDO Workshop on
Technology on Reducing Post-harvest Losses and
Maintaining Quality of Fruits and Vegetables
2-11

An Overview of Postharvest Biology and Technology of Fruits and Vegetables

Chun-Ta Wu

Department of Horticulture, National Taiwan University, Taiwan, ROC

Abstract

Harvested fresh fruits and vegetables are living products. They are characterized by high moisture content, active metabolism, and tender texture; as a consequence, significant losses resulting in senescence, desiccation, physiological disorders, mechanical injuries, and microbial spoilages occur at any point from harvest through utilization. The main objective of postharvest technology is to restrict deterioration of produce along the postharvest chain, and to ensure that maximum quality value for the produce is achieved. Temperature management and dehydration control are the essential and the two most important strategies to extend shelf life and retain quality of horticultural perishables. The other supplements such as controlled atmospheres and modified atmospheres, 1-methylcyclopropene fumigation, and heat treatments can further enhance their storability. Over the past few years, development and application of effective, safe, and environmental-friendly postharvest technology for edible horticultural commodities have become and will continue to be the number one concern by fresh produce handlers and consumers.

Introduction

Fruits and vegetables are considered as a commercially important and nutritionally essential food commodity due to providing not only the major dietary source of vitamins, sugars, organic acids, and minerals, but also other phytochemicals including dietary fiber and antioxidants with health-beneficial effects. In addition, fruits and vegetables provide variety in color, shape, taste, aroma, and texture to refine sensory pleasure in human's diet. There is an increasing demand for fresh produce at the consumer level, because of the raising awareness of people about the superior of fresh, natural foods than processed products resulting in the active encouragement by health agencies and public media as well as several medical researches demonstrating various health benefits of fresh produce consumption[13]. Fruits and vegetables, unfortunately, are highly perishable in nature and may be unacceptable for consumption if not handling properly following harvesting[3,4,7,13]. Furthermore, fresh horticultural products are important items of international commence after the globalization of trade and free trade agreements. Longer shipments and distribution periods may eventually increase the potential of heavy losses; therefore, the importance of proper cares and techniques for handling fresh produce after harvest has been recognized and emphasized. **Postharvest**, the connecting link between the grower and the

consumer, is concerned with the biology of harvested plant materials and uses this knowledge to develop effective and feasible handling technologies that delay the rate of senescence[3,13]. The main purposes of applying postharvest technology to harvested fruits and vegetables are to diminish losses between harvest and utilization, to maintain best possible quality (appearance, texture, flavor, and nutritive value), and to ensure food safety [3,4,13].

All fresh fruits and vegetables are living tissues. Due to high moisture content, active metabolisms, tender nature, and rich in nutrients, they are vulnerable to dehydration, environmental stresses, mechanical injury, and pathological breakdown and are usually considered to be highly perishable[3,4,7,13]. These characteristics strongly limit the storage life of fruits and vegetables and cause significant deterioration following harvest. Postharvest losses can occur at any point in the production and marketing chain. It is estimated that the magnitude of these losses due to inadequate postharvest handling, transportation and storage in fresh fruits and vegetables is relatively higher, 20-50%, in developing countries when compared to 5-25% in developed countries[4]. Kader (2005) commented that complete elimination of postharvest losses may be impossible and uneconomical, but to diminish them by 50% is possible and desirable[5]. Minimizing postharvest losses of produce that has invested substantial labor, materials and capital to grow is a very effective way to increase food availability without further boosting crop production[4,13]. To reduce these losses, understanding the causes of deterioration in fruits and vegetables is the fundamental step, and followed by utilizing appropriate and affordable technological procedures to delay senescence and conserve quality of produce. In this paper, the factors involved in deterioration of harvested fruits and vegetables are discussed first, and then some postharvest technologies generally used in the commodities are briefly summarized.

Factors Involved in Postharvest Loss of Fruits and Vegetables

The actual causes of postharvest loss in fresh fruits and vegetables are many and commodity specific, since horticultural products are diverse in morphological structure, composition, developmental stages, and general physiology[13]. However, the main causes of produce deterioration are continuous metabolism and growth, water loss, physiological disorders, mechanical damage and pathological breakdown[3,13].

1. Continuous Metabolism and Growth

Since fruits and vegetables are living biological systems, they are subject to metabolic and developmental changes even after harvesting. It is well established that the quality of the harvested commodities cannot be improved further but it can be retained till their consumption if the rate of metabolic activities are reduced by adopting the appropriate postharvest handling operations. One of the important parameters determining the metabolic activity of a horticultural product is its respiration rate, which is usually associated with the commodity deterioration. **Respiration**, involving enzymatic oxidation of organic substrates with energy production resulting in O_2

consumption and CO_2 and water production, represents sum of total of all the metabolic activities of the tissue[3,5,7,13]. Respiratory rate of produce after harvest is reversely proportional to its storage life, i.e., the higher the rate of respiration, the shorter is the storability, because the produce is detached from its source of photosynthates and is entirely dependent on its own food reserves[5,7]. Respiration rate of a produce is dependent on a wide range of variables, including commodity and environmental factors[3,5,7,13]. Among the external factors affecting respiratory rate of fresh fruits and vegetables after harvest, temperature is considered the most important in modulating this physiological parameter[3,5,7,13]. **Temperature quotient (Q_{10})**, which is the ration of the rate of a reaction at one temperature (T_1) versus the rate at that temperature plus 10℃ [(rate at $T_{1+10℃}$)/rate at T_1], is the measure usually quoted for respiration to give a general estimation of the effect of temperature on the overall metabolic rate of produce[5,7,13]. Within the 5℃ to 25℃ range, the velocity of respiration increase 2 to 2.5 folds for every 10℃ rise in temperature for most harvested produces, i.e., Q_{10} = 2.0-2.5. The gas composition, such as O_2, CO_2, or ethylene, surrounding the horticultural produce, also exerts a great impact on both its respiratory and general metabolic rate. The postahrvest technologists are mainly concerned with slowing down the rate of respiration for maintaining quality and maximizing storage life.

Ethylene, the simplest olefin, is a gaseous phytohormone that can significantly elicit the respiration and senescence processes of a number of harvested fruits and vegetables in trace amounts (less than 0.1 μL L^{-1}) [3,7,8,11,13]. In higher plants, ethylene is produced from methionine via three enzymatic reactions: (1) methionine is converted to *S*-adenosyl-L-methionine (*S*-AdoMet) by *S*-AdoMet synthetase; (2) the conversion of *S*-AdoMet to **1-aminocyclopropane-1-carboxylic acid (ACC)**, the immediate precursor of ethylene, is the rate-limiting step catalyzed by **ACC synthase (ACS)** in this pathway; (3) **ACC oxidase (ACO)** degrades ACC to release ethylene[8,11,13]. The major physiological responses regulated by ethylene in harvested horticultural products include chlorophyll degradation, fruit ripening, senescence, and abscission of plant organ[3,8,11,13]. Since exposure to ethylene can be detrimental to quality of most fresh horticultural commodities, ethylene is of major concern to all produce handlers during postharvest period.

Ripening is a developmental phase spanning from the last stage of maturation through the earliest stage of senescence in fleshy fruit and is commonly observed in many fruit products after harvest[1,,3,7,11,13]. It is widely accepted that fruit ripening is a senescence process, due to a breaking down of the cellular integrity of the tissue[1,7,13]. Several biochemical and physiological events involving in change of color, firmness, flavor, and aroma take place in this transitional period, which results in the transformation of unripe fruit into an edible ripe product[1,3,8,11,13]. Based on whether or not they produce a peak in respiration, the ripening behavior of fruits has been categorized as being either climacteric or nonclimacteric[1,3,7,13]. **Climacteric fruit**, such as apple, banana, and tomato, is defined by the dramatic increase of respiration rate and ethylene release during ripening. **Nonclimacteric fruit**, such as citrus, grape, and strawberry, on the other hand, displays a steadily decline in the respiratory pattern without significant enhancement of ethylene

production in this stage. This physiological behavior of the fruits has a great importance in the postharvest biology and technology of these commodities. For example, to obtain greater degree of storage and marketing flexibility, climacteric fruit is usually harvested at mature green (unripe) stage since it can ripen normally after harvest. Conversely, nonclimacteric fruit must be harvested only when fully ripe. Several lines of evidence have demonstrated that ethylene is the crucial phytohormone regulating timing of ripening in climacteric fruits[1,3,11]. Although nonclimacteric fruits typically produce little ethylene after harvesting, many have still been shown to be affected by exogenous ethylene during storage. As a consequence, ethylene control is a target for shelf-life manipulation for both climacteric and nonclimacteric fruits[3,11,13].

Active resumption of growth in harvested produce, such as sprouting and/or rooting of tuberous and bulbous crops, elongation and curvature of stem vegetables, and seed germination inside fruits, is undesirable and lead to great reduction in market quality and accelerated deterioration.

2. Water Loss

Fruits and vegetables typically contain 80-90% water in fresh weight basis[3,13]. Severed plant organs are much more susceptible to water loss, because the water replenish system is eliminated at harvest. As little as 5% loss in water has adverse effects on appearance, salable weight, and texture quality of many perishable commodities; therefore, the desiccation resulting from moisture loss is a main cause of deterioration during postharvest. **Transpiration** through stomata is the major way of moisture loss in fresh horticultural commodities[3,7,13]. The other paths of water loss are stem scare, lenticels and the cracks resulted from mechanical injury.

Produce characteristics, namely morphological and anatomical characteristics, surface area/volume ratio, surface injury, and maturity stage influence transpiration rate. For example, products like leaf vegetables with a large surface to volume ratio will lose greater percentages of their water far quicker than large spherical fruits. Loose leafy lettuce loses water more rapidly than head lettuce. Beside commodity factors, the rate of postharvest water loss is dependent primarily on the external **vapor pressure deficit (VPD)**, though other environmental factors will influence the situation[3,7,13].

3. Physiological Disorders

Physiological disorders of fruits and vegetables arise from exposure of the commodities to undesirable postharvest and preharvest environmental conditions or mineral imbalance arising during growth[3,7,13]. Low temperature-related, respiratory and nutritional disorder are particularly problematic.

The improper temperatures may lead to the disturbance in the normal metabolism of the harvested products. **Chilling injury (CI)** by low (< 10-13℃) but non-freezing temperature is

observed common with tropical and some subtropical origin fruits and vegetables[3,7,12,13]. Potential symptoms of CI are surface lesions, external and internal discoloration, water-soaking of tissues, abnormal ripening, and accelerated decay. The symptoms of CI may not be evident while the produce is held at chilling temperature but becomes noticeable only after being transferred to room temperature. **Freezing injury**, on the other hand, results from holding the commodities below their freezing temperatures[3,7,13]. The damage from ice crystals formed in tissues usually results in immediate collapse of the tissues and total loss of the commodity.

Nutritional disorders originate from preharvest mineral imbalance are sometimes appear only after harvest in products. Calcium is associated with more postharvest-related deficiency disorders than any other mineral[3,13]. **Bitter pit of apples** and **blossom-end rot of tomato** are well-known calcium deficiency disorders in horticultural crops[3,13]. Respiratory disorders are associated with very low O_2 (< 1%) and/or high CO_2 (> 20%) concentrations in and/or around harvested produce in storage or packaging condition[3,5,13].

4. Mechanical Damage

Mechanical damage of fruits and vegetables, as a consequence of inappropriate harvesting and postharvest handling, is one of the most common and severe defects of horticultural products. It not only directly affects appearance attributes (skin and flesh lesions and browning) but also creates sites for pathogen infection and water loss. Furthermore, physical injury stimulates ethylene production and respiration in plant tissues, which can lead to acceleration of senescence[3,7.13].

5. Pathological Decay

As mention above, fruits and vegetables are characterized contain a wide range of organic substrates and high water activity, and thus are good substrates for microbial spoilage. Accordingly, a significant portion of losses of fresh produces during postharvest is attributed to diseases caused by fungi and bacteria[3,7,13]. The acidic tissue of fruits leads to their spoilage being predominately by fungi, whereas vegetables having pH above 4.5 are commonly attacked by both bacteria and fungi. The most common pathogens causing decays in fruits and vegetables are species of the fungi *Alternaria*, *Botrytis*, *Botryosphaeria*, *Collectotrichum*, *Diplodia*, *Monilinia*, *Penicillium*, *Phomopsis*, *Rhizophus* and *Sclerotinia* and of the bacteria *Erwinia* and *Pseudomonas*[13]. Fruits and vegetables generally possess considerable resistance to potential pathogens during most of their postharvest life. Senescence, ripening, or stresses, e.g., mechanical damage and chilling injury, may render them susceptible to infection by pathogens[3,7,13]. Although most pathogens totally rely on physical injury or physiological breakdown of the commodity to invade host tissues, a few such as *Colletotrichum* are capable to actively penetrate the skin of healthy product[3,13]. Mirobial infection can occur before and/or after harvest. **Latent infection**, or **quiescent infection**, is the state in which a product is infected prior to harvest with

no obvious symptom developing until the pathogens are reactivated by onset of conducive conditions, such as fruit ripening or favorable temperatures. Diseases with latent infection, e.g. anthracnose diseases of tropical fruit caused by *Colletotrichum gloeosporioides*, often causes rapid and sever postharvest decay since the infected produce cannot be sorted out easily before storage[7,13].

Technologies to Improve Postharvest Quality

The main objective of postharvest technology is to restrict deterioration of produce as much as possible along the postharvest chain, and to ensure that maximum market value for the produce is achieved. The technologies involved in postharvest handling of fruits and vegetables are enormously complicated because the products are divergent in their structural origin, developmental stage, and physiological status, and perishability[7,13]. However, to protect the harvest products by proper packaging, minimize their respiration rates and developmental events, such as growth or ripening, by low temperature storage, or manipulating their physiology, eliminating or suppressing microbial activities are the basis of all the postharvest techniques. Some commonly used and fundamental postharvest technologies are summarized below.

1. Temperature Management

Temperature management is the most effective tool for maintaining quality and extending the shelf life of fresh fruits and vegetables after harvest, as temperature affects the rate of most biochemical, physiological, physical, and microbiological reactions contributing to postharvest deterioration[3,7,13]. Thus, storage at low temperature has been the main strategy to preserve harvested horticultural products[3,7,13]. The major effect of the low temperature application between harvest and end use is a reduction of the produce metabolism and consequently a delay of the evolution of the parameters related to quality loss and senescence. Typical Q_{10} values within the physiological temperature range for deterioration are approximately 2 to 3 for most horticultural products[5,7,13], implying that storability would be double or triple for every 10℃ reduction.

It is necessary not only to chill the harvested product but to cool it as quickly as possible in order to maintain the commodity as close to its condition at harvest. **Precooling** is a process that removes field heat from freshly harvested products by a cooling treatment before shipment, storage or processing[3,13]. Because of slowing down the rates of their respiration and water loss, as well as the growth of decay microorganisms around, prompt cooling after harvest is desirable for retarding the deterioration of fruits and vegetables, especially when harvesting was conducted during hot weather. The beneficial effects of precooling on prolonging shelf life is more pronounced in metabolically active and highly perishable products, such as small berry fruits, flower and stem vegetables[3,7,13]. The major precooling methods include room cooling, forced-air cooling, hydrocooling, packaging-icing, and vacuum cooling, each one having different advantages for each particular produce and/or practical applications[3,13]. **Forced-air cooling**,

involving pushing cold air down by an induced pressure gradient through packages and around each item of produce, is adaptable to a wider range of commodities than any other cooling method.

After precooling, the produce should be directly transferred to storage at the optimum temperature, which is usually just above that which will cause chilling or freezing injury. Refrigeration or low-temperature storage has been considered the most efficient method to retain quality of most fruits and vegetables due to its effects on reducing respiratory rate, water loss, ethylene emission, senescence and microbial spoilage. However, the use of refrigerated storage is limited by the chilling sensitivity of many products and by its cost occasionally[3,7,12,13].

Temperature management begins with the time of harvesting[3,13]. It is often good practice to harvest during the coolest part of the day to reduce product warming. Protect harvested produce from exposure to direct sunlight when accumulating fruits or vegetables in the field; then rapidly deliver them to packinghouse for precooling. An unbroken **cold chain** throughout the postharvest handling system is essential to extend and ensure the shelf life of horticultural perishables[3,13].

2. Control of Water Loss

The basic principle of minimizing water loss from fruits and vegetables during postharvest period is to decrease the capacity of surrounding air to hold additional water[13]. It can be achieved by commodity treatments, such as surface waxing or coating and plastic film wrapping, or by environment manipulations, such as reduction of VPD between the product and air via lowering temperature and/or raising **relative humidity (RH)**, or control of air movement[3,7,13]. Despite the fact that maintenance of a high relative humidity atmosphere is necessary to arrest water loss, very high RH (> 95%) can encourage the proliferation of bacteria or fungi and, therefore, pathological breakdown. In general, it is recommended that 90% and 98-100% RH are the optimal compromise condition for fruit and leafy vegetable storage, respectively[3,13].

3. Atmosphere Modification

Alternation in the concentrations of the gases around horticultural products can significantly increase their storage life, resulting from reduction in respiration rate of produce, retardation of senescence, and growth inhibition of many spoilage microorganisms. The terms **controlled atmospheres (CA)** or **modified atmospheres (MA)** refer to create an atmospheric composition around the produce which is different from normal air by addition or removal of gases[3,6,13]. The levels of O_2, CO_2, N_2 and ethylene in the atmosphere may be manipulated. In practice, CA and MA usually involve reducing O_2 levels below 5% and/or elevating CO_2, levels above 3%[6]. The only difference between CA and MA is that the gas control is more precise in CA than in MA[3,6,13]. The tolerance or susceptibility of produce to the injury caused by decreased O_2 and increased CO_2 concentration is an important factor for successful development of CA and MA technology. **Modified atmosphere packaging (MAP)** is an alternation in the composition of gases

surrounding fresh produce by respiration and the aid of plastic films with selective permeability to the gases[3,6,13]. Recently, a rapid expansion of MAP has occurred for minimally processed (fresh-cut) fruits and vegetables. The beneficial effects of CA and MA storage include prolonged storability of perishables by arresting respiration and senescence, reduction in ethylene biosynthesis and sensitivity of produce, decrease in incidence and severity of decay and control of fungi, bacteria and pests in selected commodities. However, when used incorrectly, the potential harmful effects of CA and MA technology are aggravation of physiological disorder, irregular ripening of fruits, development of off-flavor, and increase of susceptibility to decay[3,6,13]. The difference is often very small between beneficial and harmful CA and MA combination. In addition, CA and MA are considered as an adjunct to refrigerated storage and not substitutes for proper temperature and RH management[3,6].

4. Treatments to Reduce Ethylene Damage

The presence of ethylene in the atmosphere has been a major concern not only for unripe climacteric fruits but also for non-climacteric fruits and vegetables during the postharvest handling, because it accelerates ripening, senescence, abscission and physiological disorders[3,7,11]. The action of ethylene must be avoided for most horticultural products during storage and transportation; therefore, technologies to limit the ethylene biosynthesis of tissue, fast remove emitted ethylene from the surrounding atmosphere of produce, and create the environment of storage unfavorable for ethylene action are utilized widely in commercial practice[13]. A simple physical method to prevent ethylene accumulation is to ensure good air circulation inside the storage room and ventilation with external air if needed[13]. Ethylene absorbents, such as potassium permanganate on vermiculite in packages have been tried with success to oxidize the ethylene release from fresh products[13].

Recently, the successful registration and commercialization of **1-methylcyclopropene (1-MCP)** for application in edible horticultural products has opened an exciting new era of reducing ethylene damage in marketing quality and storage life of fruits and vegetables after harvest[2,10,13]. 1-MCP is an antagonist of ethylene responses and acts by occupying ethylene receptors such that ethylene cannot bind and its signaling is blocked[2,13]. The positive chemical attributes of 1-MCP as an odorless gas, active at very low concentrations, persistent effects, nontoxic mode of action and negligible residue have led to intense interest as a commercial technology.

5. Heat Treatment

Nowadays there is an increasing awareness among consumers that the chemical treatments of fruits and vegetables to control pests, pathological microorganisms, and physiological disorders are potentially harmful to human health and environment, there is a trend towards the use of natural compounds or physical treatments for insect disinfestations and disease control in fresh

horticultural produce[3,9,13]. Heat treatments have actually been considered as environmentally friendly methods of deterioration control, either alone or in combination with other methods. The most common used heat treatments include hot water immersion, forced-hot air treatment, and vapor heat treatment[9]. Hot water immersion has been used classically for fungal control and vapor heat treatment was developed specifically for insect control, while forced-hot air treatment is used for both fungal and insect management[9].

The tolerance of produce to heat treatments must be carefully evaluated, since the inappropriate heat treatments leads to heat injury. The fact that the condition difference between beneficial for quality maintenance and causing damage to the commodity under treatment is a matter of only a few degrees has strongly impeded the scale-up application of heat treatments[9,13]. The threshold temperature and uniformity in space throughout the entire duration of the process are the two most important factors that should be taken into account during heat treatment process development on an industrial scale.

Concluding Remarks

In conclusion, today fresh produce consumers are not only looking for traditional quality attributes such as appearance, firmness and flavor, but also value other parameters, including nutrients and bioactive compounds availability, antioxidants, and aroma. There is growing concern about food safety and environmental issue. Therefore, a major goal for postharvest handling of horticultural products should emphasize on both effective preservation of the quality attributes already mentioned and the use of appropriate technologies considered to be safe and low or no adverse environmental impact[3,13].

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Application of Postharvest Technologies for Vegetable Crops in Taiwan

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Abstract

The production of vegetables in Taiwan has the following characteristics: year-round production, multiple weather conditions, plentiful in species, and small farm system. Vegetable production and marketing teams are formed by growers that produce same kinds of vegetable in a region. It is a very common type of professional vegetable grower's organization. They market their products under the same brand name by cooperative marketing. Due to faulty handling systems, vegetable crops suffered significant losses after shipment to Taipei in the 80's. The recognition and application of postharvest technology in the late 80's helped to improve the quality of vegetables and reduced the losses. The development of precooling methods, from top-icing and hydrocooling to forced-air cooling and vacuum cooling were considered as significant progresses in the postharvest technology in Taiwan. The extensive use of refrigerated storage by the growers helped maintaining the freshness of harvested vegetables. Both controlled and modified atmosphere storage systems had been studied and promising results were reported for short term storage of leafy vegetables. A high-temperature storage system, based on the thermo-dormancy phenomenon, was developed to extent the storage life of garlic bulbs in Taiwan.

Vegetable Production in Taiwan

Taiwan is an island with total area about 36,000 square kilometers. It locates across the tropics and the subtropics and the weather condition allows Taiwan to produce vegetables year-round. More than 70% of the island is covered by hills and high mountains. On the southern-west side of the island, there is a vast plain, which is the major location that most of the vegetables are produced. Most of the warm-season vegetables are grown in the summer, from May to September; and many cool-season vegetables are grown during the winter. In the summer, some of the cool-season vegetables such as cabbage and tomatoes are moved to the mountain region, where the temperature is cooler in the summer. Due to its multiple weather conditions, there are over 180 vegetables listed in literature, and there are about 100 kinds of vegetable sold regularly in the market.

In 1961, the total planting area of vegetables was about 90,000 ha and the total production of vegetables was about 500,000 tons. The area increased rapidly in the 60's and 70's, reaching a peak of 240,000 ha in 1980 and remained at that level for about 10 years. The total production

increased rapidly during this period reaching over 3,000,000 tons in 80's. After 1990, the total area began to decrease gradually. Currently, the planting of vegetables in Taiwan is about 150,000 ha and the annual production was about 2,500,000 tons (Fig. 1 and Fig. 2). The decrease in both planting area and total production was due to the adjustment from over-production to a stable balance state.

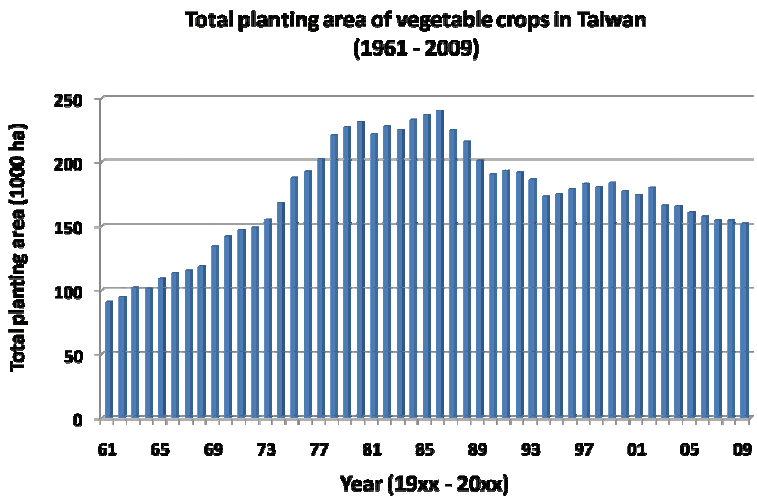

Fig. 1. Changes in total planting area of vegetable crops from 1961 to 2009 in Taiwan (Source: Agricultural Yearbook, COA)

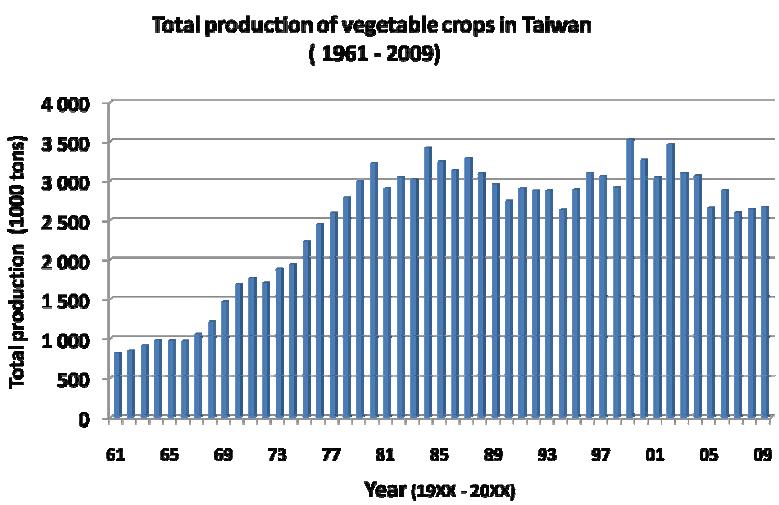

Fig. 2. Changes in total production of vegetable crops from 1961 to 2009 in Taiwan (Source: Agricultural Yearbook, COA)

Vegetable Grower's Organization and Marketing of Vegetables

Basically, most of the participants in Taiwan's agricultural production system are small farmers. Individual farmer grows their crop on a small piece of land with limited production. For vegetables, it is the grower's job to do all the harvesting and postharvest handling works. Although vegetable production areas are located sporadically all over the island, there is a tendency of centralization of specific vegetable production in a certain area. This is because many vegetables have specific demands for their growth condition, and require certain skill in their production. Therefore, vegetable growers in a region tend to grow the same kinds of vegetable that are familiar to them. As a consequence, "vegetable production and marketing teams" are formed nationwide in all major vegetable production area. This is a very common type of professional vegetable grower's organization in Taiwan. Team members produce the same kind of vegetable, grade and pack the product in uniform container and market the produce under the same brand name. This type of marketing is called "cooperative marketing", which comprises about 60% of the vegetables auctioned in the Taipei wholesale market. The cooperation among growers brings higher revenue to the grower and provides incentive to further improve their growth facilities as well as their postharvest handling techniques.

The distance between the southern end and the northern end of Taiwan is about 400 kilometers. Since the road system is well established all over Taiwan, it usually takes less than 8 hours for vegetables to be shipped from farm gate to destination market. Usually, vegetables were harvested in the morning, then went through all the handling procedures and finally packed in shipping containers. In the late afternoon, the packed vegetables were loaded onto truck and shipped to the destination market. The vegetables were sold to wholesale buyer the next day before day-break and arrived at the retail stand by the morning. Generally, it takes about one day for vegetables to reach the consumer.

The Need of Postharvest Technology for Vegetables

Vegetables are perishable agricultural products. During the postharvest handling and transportation period, severe losses may incur owing to various faulty handling practices as well as adverse environmental conditions. According to a study (Hsu, 1985), during the shipment of vegetables from the production area to Taipei city, the losses of celery, Chinese cabbage and Pak-choi were 18.69, 28.08 and 20.25%, respectively; and the loss of cucumber, sponge guard, egg plant and snap bean were 15.23, 10.42, 15.14 and 14.59%, respectively. The major causes of losses in leafy vegetables, listed by ranking, were mechanical damage, decay, water loss and yellowing. The major causes of losses in fruit vegetables were decay, weight loss, mechanical damage and insect pest. These results indicated the significance of postharvest losses in vegetables.

In the 1990's, the importance of postharvest technology was recognized, because postharvest technology emphasizes the maintenance of freshness of the produce and the reduction of

postharvest losses during handling and transportation. The improvement of handling methods will increase the revenue of the grower, reduce waste and provide fresh produces to the general public. Good practice of postharvest technology involves two aspects: the first is to carry out intensive training programs to establish correct understandings; and the second is to research and develop proper handling techniques that will improve the qualities of the produce. In the past 20 years, the application of postharvest technology had helped to improve the quality of vegetables a lot and as a consequence, the postharvest losses had been reduced.

The Development of Precooling Technology

Since maintaining low temperature is considered as the most important way of preserving the freshness of products, the application of precooling technology by removing field heat quickly from harvested produce to its optimum storage temperature is considered as a very important step in postharvest handling of vegetables. Several precooling methods are developed in the past (Kader, 2002), they are room cooling, forced-air cooling, hydrocooling, top-icing and vacuum cooling. Each method differs in its principle, cost, complexity in operation and cooling efficiency.

Taiwan's summer is hot, especially in the central and southern part, where most of the vegetables are grown. From climate statistics, each year, there were more than 180 days with average daily temperatures exceeding 30℃ in these area. In early days, great losses in both quantity and quality occurred when vegetables were harvested and transported during summer time.

Since precooling had already been a common practice in the U.S and other developed countries as an effective way of preserving freshness of harvested produces (Kader, 2002), the introduction and extension of precooling became an important task in the postharvest technology in Taiwan. The recognition of the importance of precooling by the growers and the widespread using of precooling methods symbolize the advancement of postharvest technology in Taiwan.

The earliest precooling equipment was built in 1970 in Chiayi County for the purpose of cooling asparagus, which was the most important export crop at that time. The precooling operation terminated several years later after the decline in the export market, and the equipment became obsolete and abandoned. In the mean time, all the vegetables circulated in domestic markets remained warm, and the concept of precooling was little known to the growers.

Beginning from 1980, agricultural engineers initiated studies on the precooling of vegetables in Taiwan (Lee and Lin, 2005). They focused on top-icing and hydrocooling, two methods that were affordable to the grower and were easy to carry out. In the late 80's, Taiwan's economy experienced a rapid growth, and the concept of precooling was introduced to growers through extension activities. The government helped organizations of vegetable growers to build cold storage rooms through subsidy, and the concept of temperature management began to form among the growers.

Starting from 1990, postharvest technologists and agricultural engineers worked together to develop suitable forced-air cooling method in order to improve the efficiency of precooling operation (Lee and Lin, 2005). After several tests and modification, a tunnel-type forced-air cooling method was established and non-head leafy vegetables could be cooled to 5℃ in 2 hours. Since vegetables that had been cooled by the forced-air cooling method remained fresh with very good quality after shipping in refrigerated vehicles, many institutions and the military non-staple food purchaser listed forced-air cooling as a prerequisite for the vegetable they bought. By 2000, there were many organizations and grower teams that use forced-air cooling as a part of their postharvest handling operation.

Vacuum cooling is the prevailing precooling method used in the US, European countries and Japan. Vegetables are cooled rapidly in a pressure-resistant chamber under vacuum. This method has the advantage of rapid, high capacity and suitable for pre-packaged vegetables. However, it involves more sophisticated technology and requires large capital investment, and the maintenance cost is rather high (Kader, 2002). Hence, vacuum cooling was not considered as a feasible recommendation for vegetable growers in Taiwan at earlier years. After forced-air cooling method became popular, the demand for a faster and more efficient cooling method appeared. Under the collaboration between researchers and equipment manufactures, the first set of home-made vacuum cooling equipment was successfully installed in 2001 (Lin et al., 2005). With this home-made vacuum cooling equipment, two pallets of packed vegetables could be cooled to 5℃ in 20 minutes. The advantage of vacuum cooling was widely acknowledged and more than 10 sets of vacuum cooling equipment were installed in the next 3 years. Many of the major vegetable growing organizations and suppliers had shifted from forced-air cooling to vacuum cooling in recent years. The vacuum cooling method was also used in cooling of packed head-lettuce, a vegetable crop that had high potential for foreign market.

The Development of Storage Technology

The purpose of storage is to put produces in a suitable environment to maintain the freshness and to extend the duration of its availability. Based on the complexity of technology involved, storage methods for horticultural products can be grouped as common storage, refrigerated storage and controlled atmosphere storage. Although fresh vegetable crops are produced year-round in Taiwan, there are still situations that storage of harvested products is needed. In the summer, unexpected weather changes such as typhoon and torrents of rain sometimes cause sudden shortage of fresh vegetables. Therefore, short storage of leafy vegetables, ca. 1-3 weeks, is required in the summer as a preventive operation. On the other hand, underground and durable vegetables such as carrot, potato, onion and garlic are produced in the spring; long term storage of these crops are required to maintain a constant and stable supply of these crops to the market.

The most common type of storage method used by growers and shippers are refrigerated storage. The installation of mechanical refrigerated storage was very common among professional vegetable growers. Larger cooperative farms had bigger storage facilities. These cold storage

rooms served mainly for short-term storage of vegetables, such as leafy crops. It is also used as temporary storage space for packed vegetables waiting for shipping and used for the purpose of room cooling of harvested vegetables. Commercial refrigeration companies are running their business in many vegetable production areas. They provide large rooms for the long-term storage of durable vegetables mentioned above. Researchers at the Food Industry Research and Development Institute located at Hsinchu City had established a databank regarding the storage of vegetables crops in Taiwan (Chen and Liu, 1993; Chen et al., 2005). It has the information on the optimum storage temperature, relative humidity and maximum storage life of 83 vegetables.

Controlled atmosphere (CA) storage is an advanced cold storage technique that manipulates the compositions of the atmosphere surrounding the product, usually to a lower oxygen and a higher carbon dioxide concentration. Crops that are responsive to these atmospheres will have slower metabolic rate and hence longer storage life. A CA storage room is an air tight cold storage room with special equipments to monitor and to control the atmosphere composition inside the storage room. From 2000 to 2004, Huang et. al (2005) studied and established a simplified CA storage facilities for the storage of leafy vegetables. The facility was built inside a commercial cold storage room, either by plastic tent or by steel sheets. The capacity was 10 -20 tons. A number of ice-water ducts were installed inside the facility to maintain a stable temperature. An atmosphere controlling system composed of automatic gas monitor, nitrogen generator, carbon dioxide cylinder and ethylene absorbent was connected to the facility. According to their report, under the condition of 3-4℃, 2-3% O_2 and 5-6% CO_2 , < 0.2 ppm C_2H_4 ; a mixture of leafy vegetables including leafy lettuce, Pak-choi, leaf mustard, Chinese kale and cabbage were stored successfully for up to 3 weeks with > 80% of the crops still salable. They suggested that this is a workable system that can be used in short-term storage of leafy vegetables.

Modified atmosphere (MA) storage is a simplified form of controlled atmosphere storage. Products are sealed in plastic bags and stored in cold storage room. The composition inside the bag will reach a steady state similar to that of a CA condition by the action product respiration and the gas movement across the membrane. Lin (2000) reported that a modified atmosphere storage system was studied by using a zeolite-containing PE bag together with a moisture-absorbing cotton cloth. The storage temperature was 1-2℃. In this experiment, non-head leafy vegetables, including spinach, Chinese kale, Chinese mustard, Pak-choi, leafy lettuce and celery was stored for 20 days with salable rate of nearly 100%, which is much better than the result of regular PE beg storage. However, the author indicated that the initial quality of the vegetable was very critical to the success of this MA storage system.

The High-temperature Storage of Garlic Bulbs

In the literature, garlic bulbs usually can be stored at room temperature (25℃) for about 2 months. The bulb will sprout after the dormancy is over. The recommended condition for long-term storage of garlic bulb is 0-1℃, and the storage life is about 6 months. However, such storage condition is considered not feasible, because it occupied storage room for long time and

consumed a lot of electricity. Wang et al. (2005) reported that at temperatures above 30℃, garlic bulbs exhibit thermo-dormancy. This explained that garlic bulbs were stored at ambient air from May to September in Taiwan without problems, because the temperature in the summer is always between 30-35℃. The bulbs started to loss their quality after September when the ambient temperature drops below 30℃. By utilizing a heating system that maintain the temperature at 35℃, the bulbs can be stored to February with less than 25% loss (Wang et al., 2005). This high-temperature storage method was recommended to the garlic growers in Taiwan to extend storage life of their products.

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Application of Postharvest Technologies for Fruit Crops in Taiwan

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Introduction

Varied climatic conditions exist in Taiwan, where fruits of tropical, subtropical and temperate origin are cultivated. From an estimated production area of 188,000 ha, about 2,256 Mt of fruits are produced annually. Particularly, the tropical fruit crops such as banana, pineapple, mango, guava, waxapple, lychee, carambola, papaya, Indian jujube and sugarapple, etc. are favored by Taiwan and foreign consumers due to high quality by improved cultivation technologies and breeding. In the twentieth century, most tropical fruits were grown in small landholdings for local consumption. Due to inadequate availability of basic infrastructure for handling, storage, and transportation, and lack of postharvest knowledge, about 9-21% of the products was lost between the orchard and the consumer (Liu and Ma, 1983). The foreign market for tropical fruit is increasing rapidly because of increasing tourism, strangeness of exotic fruit and the trend to healthy diet. Improved postharvest technologies such as optimum condition for handling, refrigeration for cooling fresh fruit, modified atmosphere packaging for prolonging storage life, airfreight, and packaging development, which have been developed in recent years, have had an important role in enabling these change to occur. The export of Taiwan tropical fruit becomes more important day by day. This situation prompted research on postharvest aspects of fruit crops, the results of which are summarized in this paper.

Current Status of Export

Major countries that import fruits from Taiwan are Japan, Hong Kong, United States of America, Singapore, Canada, and China. According to the amount of export value, Japan's share is 35% of the total, followed by Hong Kong (20%) and USA (10%). In considering the factors of geography and consumption potential, Japan is still the most important market for Taiwan. Taiwan's fruits, including banana, lychee, guava, pineapple, carambola, and mango, are exported to foreign countries (Table 1). For a long time, banana was a major and important fruit for exporting to Japan, but the volume was in a decreasing trend in recent years. From 2003, the exporting volume was lower than 50% share in total (Table 1). In 1999, about 1000T of pineapple was exported to Japan and maintained between 400 to 950T in the following years (Table 1). The exporting status of guava, carambola, mango, and lychee was in an increasing fasion in volume. In

addition, the Japanese government granted the permits of import for papaya and pitaya into the Japanese market in 2004 and 2010, respectively. The fruits with tropical flavor, long production season and high nutritional value also have a potential for future export.

Postharvest Physiology

The research of postharvest physiology for tropical fruits fell behind those of temperate fruit. Until now, knowledge of biochemistry and physiology in tropical fruit has not yet fully enabled the management of postharvest handling for commercial benefit.

1.Respiratory Behavior

Based on fruit respiration and ethylene production patterns during maturation and ripening, fruits are either climacteric or nonclimacteric (Table 2). Climacteric fruits show a large increase in respiration and ethylene production which coincides with ripening, while nonclimacteric fruits show no change in respiration and ethylene production. The deterioration is different between climacteric and nonclimateric during postharvest. Removing ethylene from the atmosphere around the climacteric fruits before-climacteric-rise is the preferred method of preventing deterioration and senescence of ethylene-sensitive fruits. In particular, some guava cultivars are climacteric such as ‘Bai Bar’, ‘Jong-Shan-Yueh Bar’, ‘Li-Tzy Bar’, and ‘Dar- Dih Bar’, and some cultivars are nonclimacteric such as ‘Tai-Kuo Bar’, ‘Shyh- Jii Bar’, ‘Jen -Ju Bar’, and ‘De-Wang Bar’ in Taiwan (Lin, 1998). The ripening of climacteric guava is faster than nonclimacteric guava. Nonclimacteric guava is preferred for export, instead of climacteric guava, due to poor storage potential of the later. As with guava fruit, the respiratory behavior of carambola fruit is not clear.

Table 1. Expor volume of Taiwan fruit crops. (tons)

Year	Mango	Guava		Pineapple	Banana	Lychee, Longan			Carambola		
	Japan*	Canada	China	Japan	Japan	Canada	Japan	USA	USA	Canada	China
1999	35.8	98.2	—	1007.6	44915	963	933	1191			
2000	101.2	94.9	—	835.5	42619	661	576	1910			
2001	109.1	117.5	—	946.2	25644	765	286	1959			
2002	124.2	365.0	4.0	368.6	24744	694	186	2570	203	24	0.1
2003	84.8	797.8	27.9	847.5	33129	753	79	2643	406	207	84.2
2004	502.3	1589.1	23.8	1000.1	18140	531	161	2717	497	393	105.3
2005	481.1	976.9	176.3	848.3	15218	278	198	1615	358	396	173
2006	429.9	1173.8	87.2	432.7	16022	50.2	108.5	1186	509	305	246.1
2007	786.8	1682.9	45.8	459.5	19142	296.4	102.2	1435	371	399	111.0
2008	838.1	1302.3	53.5	665.5	9154	235.7	124.0	624	297	337	150.9
2009	993.1	1254.7	208.1	866.1	8863	499.7	130.9	708	223	213	206.1

Table 2. Fruit classification by respiratory behavior.

Climacteric	Non-climacteric
Avocado	Carambola **
Banana	Lychee
Cherimoya	Longan
Guava *	Pineapple
Mango	Waxapple
Papaya	Guava *
Indian jujube	
Passionfruit	

* "Li-Tzy Bar","Jong-Shan-Yueh Bar", "Bai Bar",and"Dar-Dih Bar"are climacteric, "Jen-Ju Bar", "Shyh-Jii Bar", "Tai-Kuo Bar", "Shui-Jing Bar",and "Di-Wang Bar"are nonclimacteric fruit respectively (Lin,1998).

** ，"Ruen-chii"and "Er-lin"may be climacteric fruits (Shiesh,1986).

Shiesh (1987) and Mitchan and McDonald (1991) suggested that carambola fruit is climacteric based on rising respiration, but Oslund and Davenport (1981) indicated that the respiration rise was induced by infection from microorganisms. They suggested that carambola fruit is nonclimacteric. It is necessary to do further research on carambola respiration behavior.

2.Respiration and Ethylene Production

In general, the rate of deterioration of harvested fruits is proportional to their respiration rate. Some tropical fruits are classified according to their respiration rate in Table 3. The respiration rate is affected by cultivation condition, maturity and climacteric status, and is also cultivar specific.

As a plant hormone, ethylene regulates many aspects of growth, development, ripening and senescence. It also plays an important role in fruit abscission. Fruits are classified by respiration in Table 3 according to their ethylene production rate. There is no consistent relationship between the capacity of ethylene production and the perishability of a given fruit; however, the exposure to ethylene accelerates ripening or senescence in most fruits. Ethylene-sensitive fruits should not be mixed with ethylene-producing fruits during long-distance transport.

3.Chilling Injury

Controlling product temperature is the most important method of slowing quality loss in perishables and extending the shelf life of fruits. Exposure to undesirable temperatures results in many physiological disorders, such as chilling injury. Chilling injury occurs in some fruits (mainly those of tropical origin) held at temperatures above their freezing point and below 15℃, depending

upon fruit kind. Chilling injury symptoms become more serious and noticeable upon transfer to higher temperatures. The most typical symptoms are surface and internal discoloration (browning), internal breakdown, pitting, scald, uneven ripening or failure to ripen, off-flavor, and surface decay (Table 4). Fruit maturity and cultivars may influence the susceptibility to chilling injury. Partial to complete control of chilling injury symptom development have been achieved by temperature conditioning, intermittent warming, heat treatment, polyethylene bagging, and waxing (Table 4).

Table 3. Tropical fruits classified according to the respiration and ethylene production rate at 20℃.

Group	Respiration rate		Ethylene production rate	
	Level (mg/kg/hr)	Fruit	Level (μl/kg/hr)	Fruit
Very low	＜35	Pineapple, Carambola	＜0.1	Waxapple
Low	35-70	Banana（green）, Lychee, Papaya, Passionfruit	0.1-1.0	Pineapple, Carambola
Moderate	70-150	Mango、Guava、Indian jujube	1.0-10.0	Banana, Mango, Guava
High	150-300	Avocado, Banana(yellow)	10-100	Avocado, Papaya,Indian jujube
Very high	＞300	Sugarapple	＞100	Passionfruit, Sugarapple

(Kader et al.,1985；Paull,1994；Postharvest project report 1993-1998)

Table 4. Optimal storage temperature, approximate storage life, and CI symptom for some fruit in Taiwan

Commodity	Storage temp. (℃)	Approximate storage life (day)	CI symptom
Avocado	6-9	14-28	Browning, decay, abnormal ripening
Carambola	1-5	21-28	Rib browning
Atemoya	13	7-14	Peel browning, hardening
Guava			
Nonclimacteric	1-5	28-35	Scald, vascular browning
Climacteric	10	14-21	Abnormal softening
Lytchee	4	21-28	Decay, browning
Mango(Hard mature)	8-12	14-21	Scald, abnormal ripening
Mango(Ripe)	1-4	28-35	Off-flavor, peel browning
Papaya	12	14-21	Scald, abnormal ripening
Pineapple	10	14-28	Internal browning
Banana	14	14-28	Peel browning, abnormal ripening
India jujube	5	10-24	Off-flavor, peel browning

Storage Potential

Normally, storage potential is given as the storage life of a fruit held at its optimum storage condition. The storage potential is dependent on variety, pre-harvest condition, culture practice, maturity at harvest and storage environment. The storage life or potential of tropical fruits is shown in Table 4. Most tropical fruits only have a 7 to 35 day life after being harvested. The storage life of fruits such as carambola, nonclimacteric guava, and ripe mango exceeds 24 days, and makes them suitable for long distance export.

Controlled Atmosphere Storage and Modified Atmosphere Packaging

In modified atmosphere or controlled atmosphere, gases are removed or added to create an atmospheric composition around the fruit. Usually this involves reduction of oxygen and elevation of carbon dioxide concentration. Two methods differ only in the degree of control. The beneficial effects of modified and controlled atmosphere include reduction respiration rate, inhibition of ethylene production and action, retardation of ripening and senescence, and maintenance of nutritional quality (Kader, 1994). The controlled atmosphere is not commonly used due to its high cost, and currently, there is no controlled atmosphere storage room in Taiwan. The modified atmosphere packaging is used commonly in contrast to controlled atmosphere (Lange, 2000). The oxygen and carbon dioxide concentration in packaging bag are adjusted by selection in the package materials (Beaudy, 2000; Watkins, 2000). In Taiwan, carambola, guava and waxapple are usually applied with modified atmosphere packaging during transportation (Table 5).

Heat Treatment

Pre-storage heating of fruits can prevent the postharvest deterioration of commodities. The benefits obtained by a long-term (12h to 4 days) heat treatment at 38 to 46^{o}C are superior to those obtained by short-term (up to 60 min) heat treatment at 45 to 60^{o}C. Heat treatment before storage protects against pathogens and reduces decay. For example, the anthracnose in mango can be controlled by dipping fruit into 55^{o}C hot water for 5 minutes (Shiesh, 1990). Heat also protects

Table 5. Controlled atmosphere conditions of tropical fruits.

Commodity	O_2（%）	CO_2（%）
Avocado	2-5	3-10
Banana	2-5	2-5
Mango	5-7	5-10
Papaya	2-5	5-8
Pineapple	2-5	5-10
Atemoya	5	5-10
Lychee	5	3-5

(Kader,1994)

against physiological disorder, especially chilling injury (Klein and Lurie, 1992) in fruits like avocado (Nishijima et al, 1995). Heat treatment can regulate postharvest fruit ripening while maintaining the fruit quality when shelved in ambient temperature. Finally, heat enhances the effectiveness of calcium treatment. Pre-storage heating of fruit shows promise as a nonchemical method of maintaining fruit quality.

Quarantine Disinfestations of Tropical Fruits

Most tropical fruits are hosts of fruit flies or other insect pests that are subject to specific prohibitions by quarantine authorities of import countries. The purpose of disinfestations treatment is to provide an assurance to the authorities of an importing country that the commodity will be free of pests. There are many methods for insect disinfestations, including heat treatment, cold treatment, irradiation, fumigation and controlled atmosphere (Paull, 1994). A proper quarantine treatment must meet the standard of Probit 9, causing no heat injury to the commodity, and is safe to human. Some quarantine disinfestation conditions are shown in Table 6.

Table 6. Quarantine disinfestations schedules of various fruit in Taiwan.

Fruit	Import	Method
Mango	Japan, Korea, USA, New Zealand	VHT (46.5℃, 30min)
Lychee	Japan	VHT (46.2℃, 20min）+ CT (2.0℃, 42hr)
Lychee	USA	CT (1℃,15days or 1.39℃, 18 days)
Carambola	USA	CT (32, 33, 34, 35°F for 10, 11, 12 and 14 days, respectively)
Papaya	Japan	VHT (47.2℃)
Ponkan	Japan, Korea	CT (1℃, 14 days)
Pitaya	Japan, Korea	VHT (46.5℃, 30min)

VHT=vapor heat treatment ; CT=cold treatment (Bureau of Animal and Plant Health Inspection and Quarantine)

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Development and Application of Citrus Storage Technologies with Concurrent Consideration of Fruit Quality Preservation, Energy Use, and Costs

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Abstract

Three varieties of citrus fruits, namely: 'Liucheng' orange (*Citrus sinensis*), 'Ponkan' mandarin (*C. reticulata*) and 'Tankan' tangor (*C. reticulata* × *C. sinensis*) are grown in large quantities in Taiwan. They have the potential to be stored for several months under proper conditions. Desirable temperature for long-term storage is 15℃, but the fruits can tolerate short spans of lower non-freezing temperatures. High relative humidity (85 – 95%) is desirable if the fruits are not kept in plastic bags. Many pre-harvest factors and pre-storage treatments can affect the storability and post-storage quality of the fruits. Although refrigerated storage is most reliable for quality preservation and storage loss control for the fruits, it may only be needed for long terms of storage. Common storage and cave storage, which are less costly and less energy consuming, are adequate alternatives for shorter periods of storage. Selecting cooler locations to store fruits may also have a merit.

Major Citrus Varieties Grown in Taiwan

Citrus production is widespread in sub-tropical and tropical zones of the world. Being a sub-tropical island, Taiwan is abundant in citrus fruits. Major citrus varieties commercially grown in Taiwan include 'Liucheng' orange (*Citrus sinensis* (L.) Osbeck), 'Ponkan' mandarin (*C. reticulata* Blanco), 'Tankan' tangor (*C. reticulata* × *C. sinensis*), 'Wentan' pummelo (*C. grandis* (L.) Osbeck) and 'Eureka' lemon (*C. limon* (L.) Burm., f.). These five varieties count for much (86 %) of the total citrus production (473,068 M.T. in 2007) of the island. Many other varieties are produced only in small quantities each.

Lemon is an acid-type citrus fruit and 'Wentan' pummelo is an early season variety which is consumed shortly after harvest. Therefore, only three varieties of citrus, namely: 'Liucheng' orange, 'Ponkan' mandarin, and 'Tankan' tangor will be targeted in the following discussion.

A Need of Storage and Losses in Storage

Commercial harvesting season encompasses 'Ponkan' mandarin in November, 'Liucheng' orange in December, and 'Tankan' tangor in January. Earlier harvest sacrifices fruit quality, while

delayed harvest often encounters severe fruit drop and damages by insects (particularly fruit flies) and birds in addition to interference with flowering and fruit growth of the crop of subsequent year (Liu et al., 1998). Without proper storage, the fruit has only about one month of marketable life after harvest. In other words, the total marketing period of these three varieties of citrus fruits will be about four months without storage. That situation will create an over supply at the harvest season and lack of supply shortly after harvest. Therefore, a proper storage will be necessary to extend the marketing period while easing off the market pressure at the peak harvesting season.

Storage does generate some losses of fruits. The magnitude of losses is highly variable depending on variety and source of fruits, storage facilities and management, and duration of storage. It varies from one year to another also. Although no statistical or even estimate data are available, field observations revealed substantial storage losses occurred each year. Some fruits become totally unmarketable after storage; and some others decline in quality and market value. From growers' point of view, storage is profitable only if the increase in total sale revenue is greater than storage losses plus storage costs. Therefore, minimizing storage losses is a must.

Major storage troubles are button (calyx plus short stem attached to the fruit) browning or abscission, granulation of juice vesicles, albedo (mesocarp) breakdown or creasing, decay, and stem-end rind breakdown or aging. Eckert (1978) described four kinds of most common postharvest diseases in citrus fruits: stem-end rots (incited by *Diplodia natalenses* or *Phomopsis citri*), *Alternaria* rot, *Phytophthora* brown rot and *Penicillium* molds incited decay. We found all of them with stem-end rots and *Prencillium* decay being most prevailing in Taiwan citrus fruits.

In Quest of Optimum Storage Conditions

In order to develop practical storage technologies for our citrus fruits, we engaged in a series of research as well as field observations to find out optimum storage conditions and treatments for the fruits. We also wanted to know what would be the maximum storage life span for each variety under the optimum storage condition. Some of our major endeavors and findings are presented below.

Pre-storage Treatments

Citrus fruit growers as well as some commercial storage house operators in Taiwan have been engaged in citrus storage for years. They gradually developed the technologies either by try and error or in reference of earlier research results. Currently adopted pre-storage treatments for freshly harvested citrus fruits were generally sound according to our observation.

The harvested citrus fruits, with or without pre-sorting (to remove culls) or pre-sizing, are dipped briefly in a liquid mixture containing a fungicide and a plant growth regulator. The most commonly used fungicide was thiabendazole (at a concentration of 800 mg $\cdot$ L^{-1} or ppm) in the past and is iminoctadine (at a concentration of 125 mg $\cdot$ L^{-1}) at present. The latter is very effective

in controlling decay under good storage conditions. A plant growth regulator, 2,4-D, added into the dipping mixture provides some protection from premature button senescence which may encourage fruit decay. Various concentrations of 2,4-D have been applied by different users and for different varieties. Our experimental data indicated that 10 ppm had a striking effect in 'Ponkan' mandarin, but 25 to 50 ppm provided better protections and 100 ppm near perfect protection even under an adverse storage condition (data not shown). For long-term storage of 'Liucheng' oranges, 50 to 100 ppm might be necessary for satisfactory protection (data not shown). According to our experiences, 25 ppm was adequate for 'Tankan' tangor, however (data not shown). We found little, if any, adverse side effects of 2,4-D applied at above mentioned adequate concentrations. Application of up to 50 ppm for 'Ponkan' had residue levels well below our national tolerance (2 ppm) according to our most recent studies (data not shown).

After dipping and fruit-surface drying in the ambient air, the citrus fruits are wrapped in small polyethylene (0.02 mm in film thickness) bags. Larger fruits are wrapped individually, one fruit per bag. Two to three smaller fruits may be wrapped in a bag, however. The open end of each bag is then closed either by machine sealing or by hand twisting. Bagging in polyethylene films prevent the fruit from excessive desiccation and avoid spreading molds from one fruit to another via direct peel contact.

Storage Temperature

Grierson and Ben-Yehoshua (1986) stated "typical storage conditions for citrus fruits" including storage temperatures of 0 - 6.7℃ for oranges and 6 - 7℃ for 'Coorg' mandarins and the estimated storage life of the former being 6 - 8 weeks and that of the latter 8 weeks. We found such storage life span too short to satisfy our need and the storage temperature ranges unsuitable for longer storage of the varieties grown in Taiwan. We therefore conducted many experiments in search of the optimum storage temperature for each of our major citrus varieties. We still dare not say "optimum" temperatures have been found, but we have had sound basis to recommend a "proper" or "desirable" temperature for long-term storage for each variety.

'Liucheng' orange tolerated 0℃ or 5℃ cold storage for 30 to 45 days, but chilling symptoms appeared in longer storage periods (Liu, 2009). Storing 'Liucheng' at 10℃ for 60 days or longer also developed low temperature disorders (Liu, 2009) or frequent excessive decay (Liu et al., 1997). Repeated trials of 5-month long storage confirmed that 15℃ was a good temperature while 20℃ resulted in higher weight losses and occasional higher incidence of decay (Liu, 2005; Liu et al., 1997).

Storing 'Ponkan' mandarins at 5℃ for 3 months resulted in severe chilling injury followed by decay which caused almost a total loss of the fruit (Liu et al., 1998). When the results of 3 to 4 months of storage at 10, 12.5, 15 and 20℃ were compared, 'Ponkan' mandarins stored at 12.5° and 15℃ had the least storage losses and had the best quality preservation, while those stored at 10℃ appeared light chilling symptoms or slight off-flavors (Liu et al., 1998).

'Tankan' tangors stored at 0℃ for 3 months or 5℃ for 4 months developed severe chilling

injuries (Liu et al., 1998). When the results of 4 to 5 months of storage at 10, 12.5, 15 and 20℃ were compared, 20℃ resulted in higher decay and higher weight losses, while the lower storage temperature the more soluble solids depression during storage (Liu et al., 1998). It seemed, therefore, that 15℃ was the best choice for long term storage of 'Tankan'.

Based on these experiment results plus some observations made in more recent years, 15℃ is a good storage temperature for all 3 major citrus varieties grown in Taiwan. Lowering the storage temperature to 12.5℃ had little benefits for 'Ponkan' mandarin and 'Liucheng' orange while having some risks of accelerating quality loss in 'Tankan' tangor. Storing any of these 3 varieties continuously at or below 10℃ is undesirable. Storing them at 20℃ generally accelerated decay incidence and weight loss but the remaining fruits had acceptable quality.

Storage Humidity

Grierson and Ben-Yehoshua (1986) stated "typical" storage relative humidity for oranges and mandarins being 85-90%. Since practically all citrus fruits for long-term storage in Taiwan were pre-bagged in water-impermeable polyethylene films, transpirational water loss is not a problem even in storage rooms without humidity control. In one of our experiments, 'Ponkan' mandarins lost only 3.5% of weight in 3 months of storage and 'Liucheng' orange and 'Tankan' tangor lost about 5% of weight in 5 months of storage (Fig. 1). Nevertheless we conducted a series of experiments on the effect of humidity on storage weight losses of our three major citrus varieties without bagging. We demonstrated the close relationship between storage relative humidity and fruit weight loss as well as linear regressions between the weight loss and vapor pressure deficit (VPD) in 1 to 3 months of storage experiments (Liu et al., 2005a).

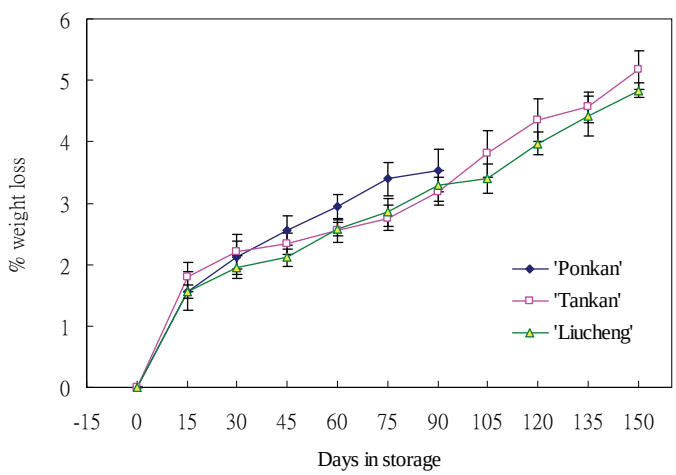

Fig. 1. Weight losses of 'Ponkan' mamdarin, 'Tankan' tangor, and 'Liucheng' orange during storage. Means of 4 tree-replicates (20 fruits per replicate) with standard deviations. (Adopted from Liu et al., 2005).

Wells (1962) reported that “at a constant temperature and for limited periods, the rate of weight loss (of fruits) increased about 50 percent for each 100 percent increase in vapor pressure deficit.” That result of 6 - 8 days of storage experiments has been cited extensively by postharvest physiologists worldwide. However, a constant percentage of weight-loss increase for each 100% increase in VPD was not found in our 1 to 3 months of storage experiments. On average of 5 experiments for 3 varieties of citrus fruits, the rate of weight loss increased 58.2±3.7%, 73.8±3.2% and 80.6±2.4% when VPD increased from 0.5 to 1.0 mbar, 1.0 to 2.0 mbar and 1.5 to 3.0 mbar, respectively (Liu et al., 2005a). At the higher VPD, the higher rate of weight-loss increase by doubling the VPD.

For practical applications, we recommend at least 85 to 90% (preferably 90%) RH for 1 month of storage and 90 to 95% (preferably 95%) RH for ≧2 months of storage when un-bagged citrus fruits are stored at 15℃. The weight losses under such conditions were below 5% and the fruit did not shrivel for up to 2 months of storage for ‘Ponkan’ mandarin and up to 3 months of storage for ‘Liucheng’ orange and ‘Tankan’ tangor (Liu et al., 2005a).

Changes in Fruit Quality during Storage

Fruit quality factors include appearance, texture and flavor. We made comprehensive studies on changes in rind color, button condition, juice content, soluble solids in juice, and acidity in the three varieties of citrus fruits in long-term storage (Liu et al., 2005). Parts of the results are summarized below.

‘Ponkan’ mandarins are half-green and half-yellow while ‘Liucheng’ oranges are nearly all yellow and ‘Tankan’ tangor is uniformly yellow orange at harvest. Stewart and Wheaton (1971) reported that Hunter a/b values were highly correlated with USDA color standards and visual color observations for citrus fruits, higher values representing more yellow to yellow orange. We used CIELAB a*/b*, which has similar meaning of Hunter a/b, to represent the color of our citrus varieties. ‘Ponkan’ mandarins had a rapid increase of a*/b* in the first month and slow increases of that in the second and third month of storage at 15℃ (Fig. 2) corresponding to rind color changes from partially green to completely yellow and then adding more orange hue. ‘Liucheng’ orange appeared a slow and steady increase of a*/b* for the first 3 months and broke the increasing trend afterward (Fig. 2). ‘Tankan’ tangors only showed a small increase of a*/b* during the first month and no further increase in later months of storage (Fig. 2). After the citrus rind has turned to yellow, further increase of a*/b* means tuning toward more orange in color.

‘Ponkan’ mandarins had little change in juice contents in 3 months of storage (Fig. 3). ‘Liucheng’ oranges and ‘Tankan’ tangors showed little changes in juice contents in 4 months of storage but had a tendency to decline slightly in the fifth month (Fig. 3).

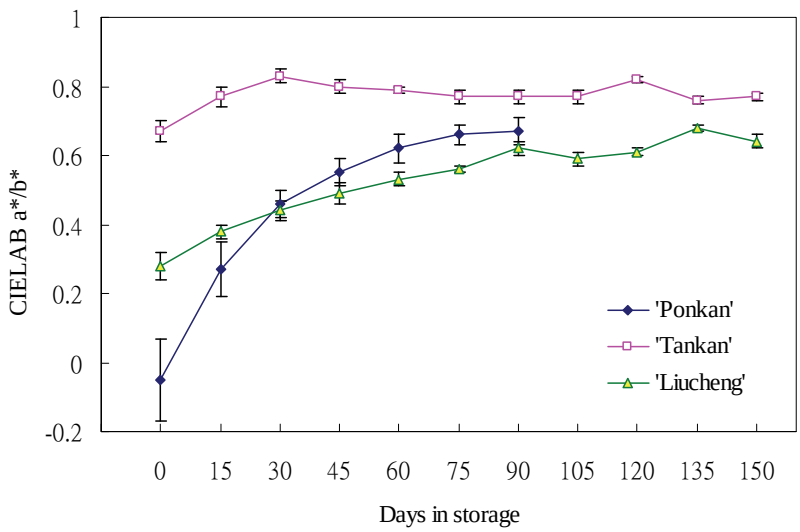

Fig. 2. Changes in CIELAB a*/b* values of rinds of 'Ponkan' mandarin (—◆—◆—), 'Tankan' tangor (—□—□—) and 'Liucheng' orange (—△—△—) in storage. Means of 4 tree-replicates (20 fruits per replicate) with standard deviations. (Adopted from Liu et al., 2005).

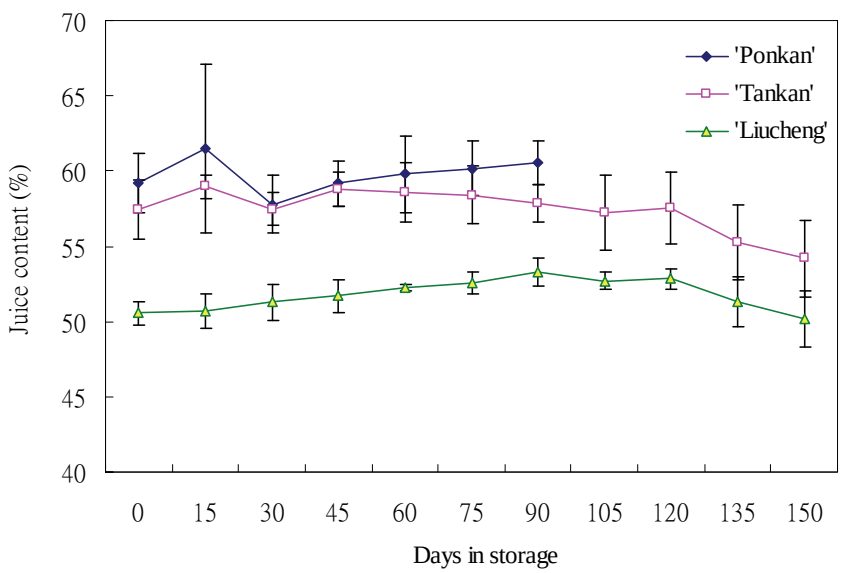

Fig. 3. Changes in juice contents of 'Ponkan' mandarin (—◆—◆—), 'Tankan' tangor (—□—□—), and 'Liucheng' orange (—△—△—) in storage. Means of 4 tree-replicates (20 fruits per replicate) with standard deviations. Data of 2003-2004 storage season.

All three varieties of citrus fruits had a trend of slight increases of soluble solids contents in the first month and slow decreases of soluble solids contents in the later months of storage (Fig. 4). ‘Ponkan’ mandarins had a slow decline of acidity in the first month and more rapid decline of acidity in later months of storage, while ‘Liucheng’ oranges and ‘Tankan’ tangors had a steady slow decline in acidity throughout the 5-month storage period (Fig. 5). When soluble solids and acidity values were converted into total soluble solids / titratable acidity (TSS/TA) ratios, ‘Ponkan’ mandarins had a slow increase in the first month and rapid increases in the second and third month while ‘Liucheng’ oranges and ‘Tankan’ tangors had steady slow increases throughout the 5-month storage period (Fig. 6).

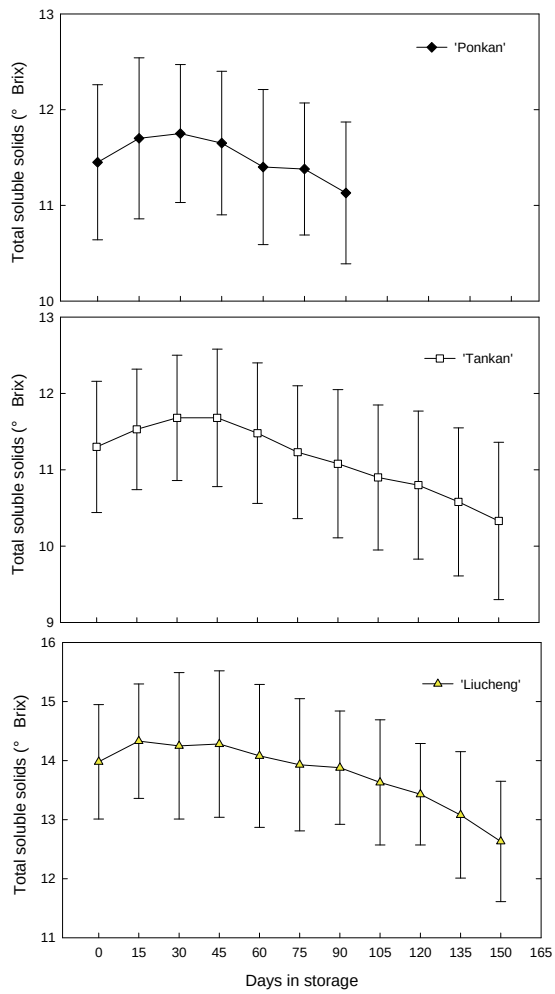

Fig. 4. Changes of total soluble solids in ‘Ponkan’ mandarin, ‘Tankan’ tangor, and ‘Liucheng’ orange in storage. Means of 4 tree-replicates (20 fruits per replicate) with standard deviations. (Adopted from Liu et al., 2005).

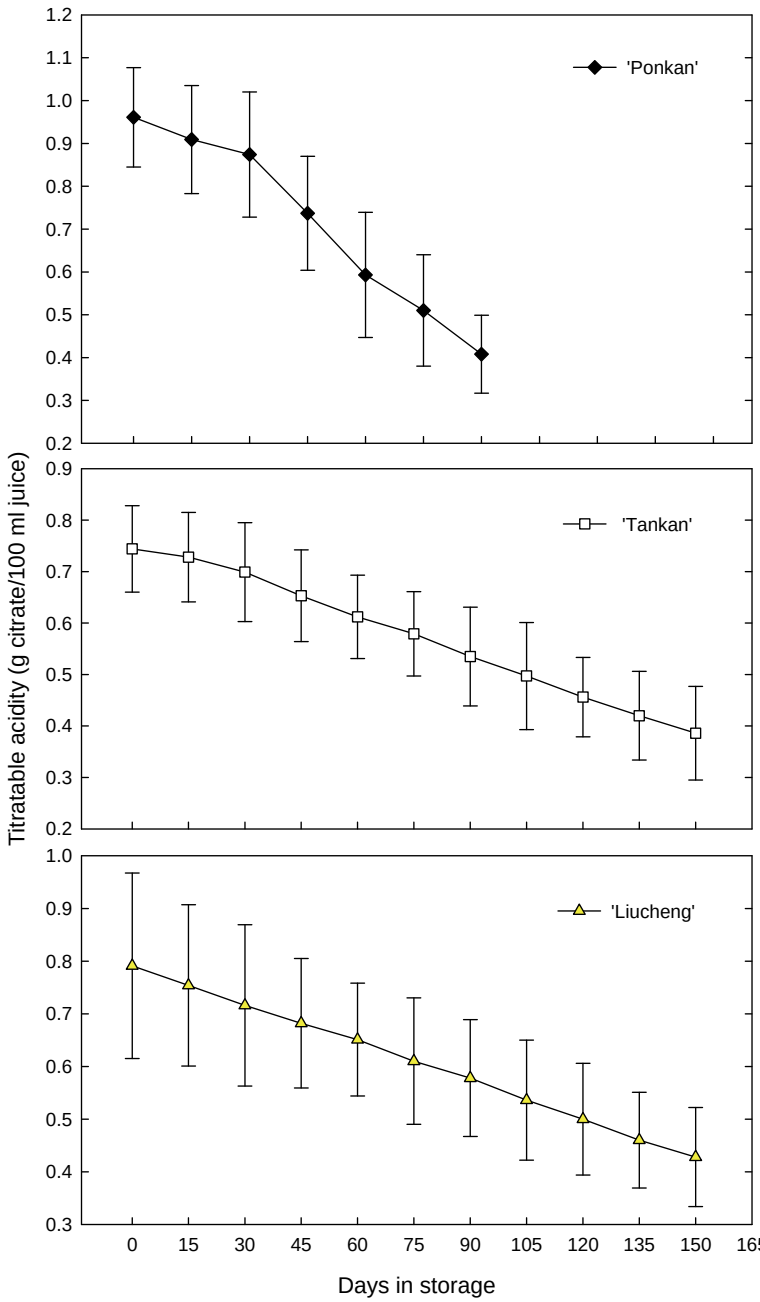

Fig. 5. Decreasing trends of titratable acidity in ‘Ponkan’ mandarin, ‘Tankan’ tangor, and ‘Liucheng’ orange in storage. Means of 4 tree-replicates (20 fruits per replicate) with standard deviations. (Adopted from Liu et al., 2005).

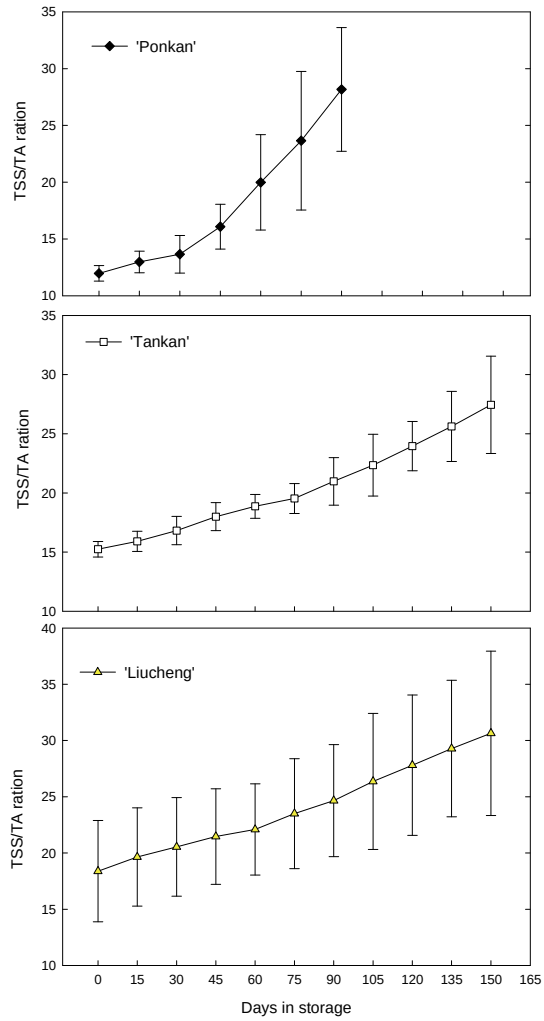

Fig. 6. Increasing trends of TSS/TA ratio of ‘Ponkan’ mandarin, ‘Tankan’ tangor, and ‘Liucheng’ orange in storage. Means of 4 tree-replicates (20 fruits per replicate) with standard deviations. (Adopted from Liu et al., 2005).

Most consumers prefer deeper orange to pale yellow or greenish yellow rind color in oranges and mandarins. Most consumers also prefer juicier citrus fruits to dryer ones. Therefore, higher a*/b*values as well as higher juice contents are desirable quality attributes. However, people’s preferences differ greatly in sweetness and sourness in citrus fruits, and therefore, difficult to define what SS and TA numbers represent the best flavor of citrus fruits. In the authors own judgment, the eating quality of all above discussed three varieties of citrus fruits improved in the first month of storage and then declined at various rates in later months of storage.

Traits of Fruit that Affect the Quality and Storability

Harvest maturity greatly affected the rind color, juice content, soluble solids and acidity, and therefore, the overall quality of three varieties of citrus fruits (Liu et al., 1998). Harvest maturity also affected decay losses in some citrus fruits. 'Ponkan' mandarins harvested late (in early December) had a tendency to have more decay than similar fruits harvested earlier (in November) when they were subjected to long-term storage (Liu, et al., 1997). 'Liucheng' oranges harvested late (near the end of December and early January) also had a trend to have more decay than similar fruits harvested earlier (earlier dates in December) when they were subjected to 4 to 5 months of storage (Liu et a1., 1997). However, no consistent relationship between harvesting date and decay in 4 to 5 months of storage was found in 'Tankan' tangors when the fruits were harvested in January through mid-February (Liu et al., 1997).

Fruit size has significant effects on the storability of citrus fruits. Large (21~23 cm in equatorial perimeter) 'Liucheng' oranges had an earlier incidence and severer cases of granulation in storage than medium sized (19~21 cm in perimeter) ones (Liu, 2009). Similar trend was noticed in 'Ponkan' mandarins and 'Tankan' tangors although no statistical data have been collected.

Fruit location on the tree before harvest affects both fruit quality (Sites and Reitz, 1949; Cohen, 1988) and storability of citrus fruits. We found that 'Ponkan' mandarins and 'Liucheng' oranges harvested from outside or on the canopy of the trees had less decay in storage and had higher soluble solids contents after storage when compared with those harvested from inside of trees (Table 1). The effects of fruit location within trees on the fruit button senescence, granulation, and acidity were less significant (data not shown).

Table 1. Effect of fruit location within the tree on fruit decay in storage and soluble solids contents after storage of 'Ponkan' mandarin and 'Liucheng' orange.[1]

Varity	Duration of storage (months)	Fruit location on the tree	Total number of fruits in each treatment[2]	Decay (%)	Soluble solids (°Brix)[3]
'Ponkan' mandarin	3	Outside and Canopy	282	1.1	10.0
		Inside	161	8.1	9.5
'Liucheng' orange	5	Outside and canopy	194	0.5	13.0
		Inside	173	3.5	12.0

[1] Means of 4 tree-replicates.
[2] The sum of 4 replicates; every replicate of the same treatment had roughly equal number of fruits.
[3] Means of 4 tree-replicates; only 20 fruits per replicate were evacuated.

Other Factors that Affect the Storability and Quality

Griserson and Hatton (1977) mentioned that preharvest factors including rootstock, weather, grove treatments, tree condition and fruit maturity, proper harvesting or not, postharvest factors involving all conditions between picking and storage, and ambient conditions between operations can affect the response of citrus fruits to cold storage. We found that 'Ponkan' marndarins harvested at about the same time from 3 orchards not too far apart had significantly different level of losses and different fruit quality after storage under same conditions (data not shown). We also found that 10 different 'Ponkan' trees on the same orchard produced fruits of substantially different quality and that the rank order of superiority of the same 10 trees varied from one year to another (data not shown). In 11 storage experiments of 'Liucheng' oranges conducted in recent years, we found dramatic differences in the incidences of storage disorders even though they were stored under the same conditions (Table 2).

Storage should be terminated before the severity of storage disorders or losses, or the fruit quality deterioration approached an intolerable point. Since there are so many preharvest and postharvest factors affecting the development of storage disorders and affecting the quality of citrus fruits, it is only next to impossible to define the storage life span of a variety even if the storage conditions are pre-determined. Furthermore, acceptable quality standards vary with different markets or different consumers; and the market price increment of the fruit during it's storage period may change the tolerance of storage losses. Therefore, the potential storage life span of a fruit can only be estimated at best but not clearly defined. Based on our experimental results and field and market observations, we estimated the potential storage life span under currently known good storage conditions being 3 months for 'Ponkan' mandarins, 4 months for 'Tankan' tangors, and 5 months for 'Liucheng' oranges.

Table 2. Percentage of 'Liucheng' oranges developed storage disorders in 5 months of refrigerated storage in 11 experiments.[1]

	% fruits developed the disorder		
Kind of disorder	The highest	The lowest	Average
Button senescence	73.7	11.0	43.2
Granulation	51.3	1.3	24.8
Mesocarp breakdown	25.0	1.3	9.6
Decay	20.0	1.3	8.1
Stem-end rind breakdown	17.5	0.0	4.0

[1] There were 4 tree-replicates, 20 to 25 fruits per replicate, in each experiment. Data adopted from Liu (2009).

Storage Methods

Common storage is widely adopted for storing citrus fruits in Taiwan. The use of refrigerated storage is on the rise in recent years. Cave storage is still in the early experimental stage, but may get into commercial application in the future. These three storage methods will be discussed below.

Common Storage

Common storage does not use mechanical refrigeration. Cooling is done by natural air or water. Good common storage does have an insulated storage room and a ventilation system either operated manually or automatically with electronic devices. When cool air is available outdoors, it is introduced into the storage room via air inlet near the floor. Warm air in the storage room is pushed or sucked out via air outlet on or near the ceiling. Electric fans may be used to accelerate air change and ventilation. When outdoor air temperature is too high, air change openings are closed, thereby temperature inside the storage room may be maintained somewhat lower than outside owing to insulation. Common storage may use very simple or rather sophisticated structures and facilities (Booth and Shaw, 1981).

Citrus growers in Taiwan use various types of common storage. The most primitive type simply pile the fruit under the plastic tent which is often installed under tree shade. Some growers store small quantities of citrus fruits in whatever space available in their own residential houses. There are also many warehouses built purposely for storing citrus fruits. Most of them have inadequate insulation and poor ventilation control, however. When citrus fruits are stored in these substandard storage facilities, rapid decline in fruit quality and heavy storage losses are often unavoidable. We assisted growers to build a couple of insulated common storage with proper air-ventilation control for demonstration purposes. We will continue to do research on the application and improvement of common storage.

Refrigerated Storage

Refrigerated storage, also known as cold storage, has at least an insulated storage room and a mechanical cooling unit. Modern cold storage also has a proper internal air circulation system, automatic control devices, and often a humidity control. Such storage facilities provide desirable temperature or temperature and humidity for the fruits.

Citrus fruits stored in a refrigerated storage regulated at the desirable temperature and humidity can best maintain their quality and minimize storage losses. We have found the desirable storage temperature being 15℃ for three major varieties of citrus fruits grown in Taiwan. We used this temperature for many storage related experiments for years and found it always suitable. Many growers and commercial storage managers use 13° to 15℃ range and avoid temperatures above 15℃. Since we found 12.5℃ also acceptable in our experiments, setting storage temperature range between 13° to 15℃ seems proper. As long as citrus fruits are bagged in polyethylene bags

in storage, humidity control in refrigerated storage is not critically important and is often ignored. If citrus fruits are stored for only about a month, bagging may not be necessary, but the relative humidity should be maintained at ≧85% in cold storage. For longer periods of storage for unbagged citrus fruits, the relative humidity needs to be maintained at ≧90% or even 95% according to our experiment results.

Cave Storage

Cave storage was once a very popular method for apples in northwest China. We learned basic principles developed there and made a lot of modification in constructing our experimental cave storage. The first one we built in a grower's orchard had the shape and dimensions (3m floor width x 3m wall height x 20m cave length, with pyramidal ceiling) very similar to apple storage caves in China. The major modifications we made were concrete lining of the cave, adoption of a modern refrigerated storage door, and installation of a ventilation fan with automatic control devices. The grower stored citrus fruits in the cave successfully in two years, but then sold the whole orchard to a developer who destroyed the cave for building vacation homes later.

We therefore build a second cave which cost much less when we had a budget difficulty. We connected several huge concrete drainage tube sections and covered them with soils. The tube has an inside diameter of 210 cm. The cave made by connecting tube sections lined up in the north to south direction has a length of 15 m. A door of refrigeration storage was installed at each end of the cave. An exhaust fan with automatic control was installed at the south end. Such a cave is far from ideal. The soil coverage above the cave should be ≧3 m but we have only about 2 m. The length of the cave should be ≧20 m but we have only 15 m. Nevertheless, it has been a useful tool for our experiments in last few years.

The theory to use cave storage for our citrus fruits is rather simple. Our citrus fruits have a desirable storage temperature of 15℃, and they can tolerate short spans of non-freezing low temperatures. In a location where non-freezing cool (0° to 15℃) ambient temperature is frequently available in winter and early spring, citrus fruits are stored in a cave. Whenever the out door temperature is lower than the temperature in the cave, open up the cave ventilation to let the cool air in to cool the fruits, the air in cave, as well as the cave wall and the soil surrounding the walls. When the outdoor temperature is higher than the cave temperature, ventilations are closed. Then the thick soil layer surrounding the cave not only provides a good insulation for the cave, but also, after being cooled, absorbs the heat generated by fruits respiration and by heat leakage from outdoors. After spring comes, outdoor cool air becomes scarce, and the cave ventilation may be closed most of the time. The cave temperature can still be kept cool for a period of time. The thicker soil layer above the cave and the cooler soil layer, the longer cool period can last. Eventually the surrounding soil temperature raises to a point beyond which maintaining an acceptable cave temperature becomes difficult. That will be the time when cave storage should be terminated. We found that a cave storage located in Miaoli County, Taiwan, has been useful for storing citrus fruits during the period between late December and April of the following year. That covers a great portion of the citrus storage season.

Temperature Differences in the Three Storage Facilities

Temperature changes during the storage season of citrus crops of 2009 were monitored in three types of storage facilities which had been installed at the same place in Tahu Township, Miaoli County. The refrigerated storage is a popular type which has been widely used in small scale operations in rural Taiwan. The cave storage has just been described above. The common storage is an insulated small room with a little ventilation control but far from ideal. Each storage facilities was only partially filled with citrus fruits during the period of temperature monitoring.

The temperature of refrigerated storage remained constant at 14° ± 1.5℃, while the temperatures of common storage and cave storage fluctuated due to the ambient temperature fluctuation. During the period from late December, 2009 to May, 2010, the 10-day interval mean temperature of the cave was significantly lower than that of the ambient air for most of the time (Fig. 7). The difference between the two temperatures was smaller up to mid-February when low ambient temperatures were available frequently, but the difference widened afterward (Fig. 7). The mean temperature of the common storage was not lower than that of ambient air for most of the time, however (Fig. 7). That indicates a need for improvement of the common storage facilities. The differences in mean maximum temperatures of the three measuring spots (ambient air, common storage and cave) were much greater than the differences in mean temperatures (Fig. 7) owing to the effects of insulations in the storage. The differences in mean minimum temperatures of the 3 measuring spots were small (Fig. 7) because ventilations in the storage were open when outdoor temperatures were low, and therefore low-temperature air could enter the storage. Another important difference was that the gap between mean maximum and mean minimum temperatures was wide in the ambient air, was subsaintially narrower in common storage, and was very narrow in cave storage (Fig. 8).

Preliminary Resuts of Storage Trials in the Three Storage Facilities

When small samples of ‘Ponkan’ mandarins were stored in the three storage facilities for 2 to 3 months in the storage season of 2008-2009, very little decay, button senescence, or granulation occurred and differences among the 3 storage facilities were insignificant (Table 3). Fruits stored in the three storage facilities also had similar rind color and soluble solids content (Table 3). When small samples of ‘Tankan’ tangors were stored in the three storage facilities in the same storage season, slight differences in the occurrence of granulation and a*/b* values were noticed in 3 months, and the differences in the two items became greater in 4 months (Table 3). Refrigerated storage and cave storage seemed to be slightly better than common storage for 3 to 4 months of storage for ‘Tankan’ (Table 3). When somewhat larger fruit samples of ‘Liucheng’ oranges in storage were examined in the subsequent storage season, the fruits in common storage seemed to have higher percentage of disorders than those in cave or in refrigerated storage after 4 months, and the fruits in cave storage had higher percentage of disorders than those in refrigerated storage after 5 months (Table 4).

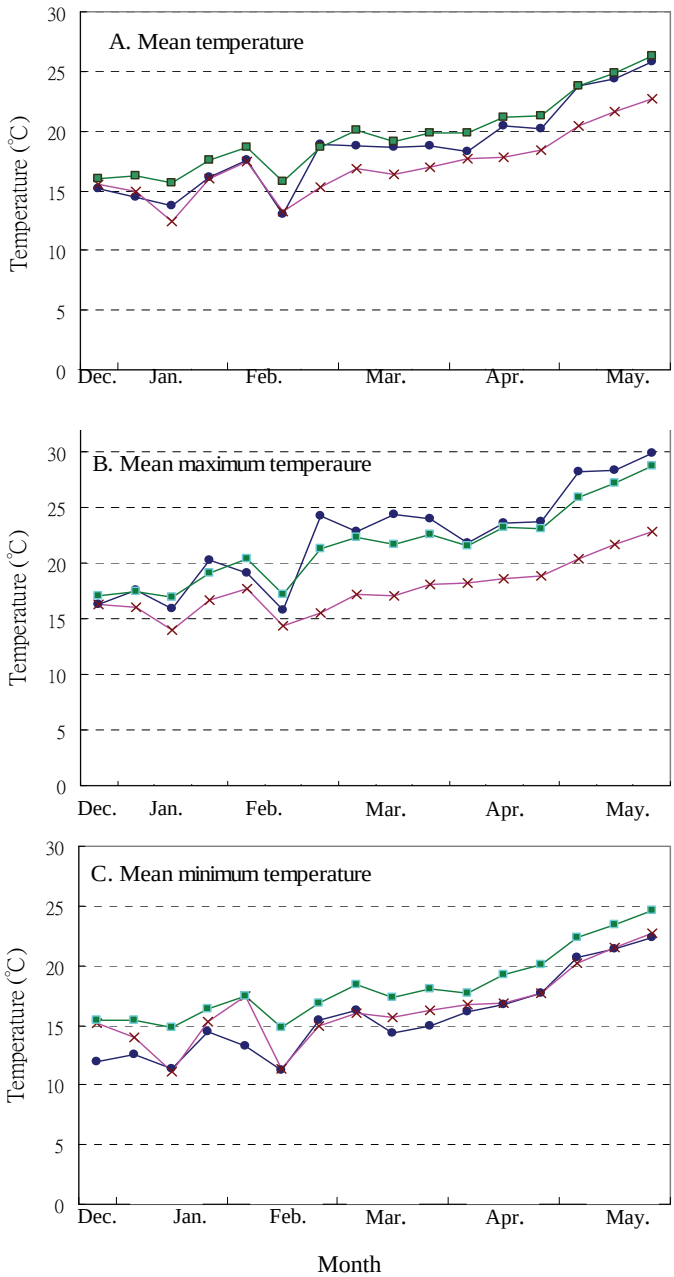

Fig. 7. Comparison of temperatures in ambient air (—●●—), in common storage (—■■—) and in cave storage (—✕✕—). Data of 2009-2010 storage season.

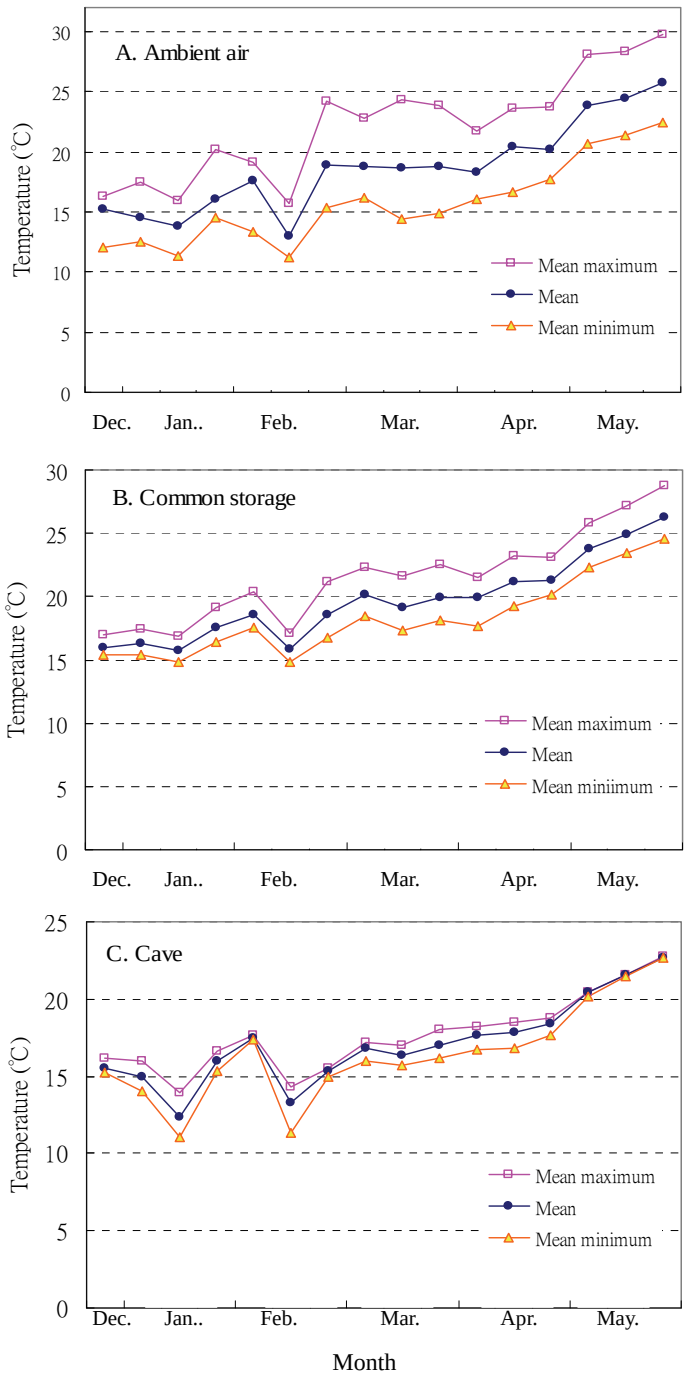

Fig. 8. Comparison of mean-maximum and mean-minimum temperature gaps in ambient air, common storage and cave storage. Data of 2009-2010 storage season.

Table 3. Differences in storage losses and post-storage quality of 'Ponkan' mandarin and 'Tankan' tangor stored in 3 types of storage facilities.[1]

Variety	Duration of storage (months)	Type of storage	Decay (%)	Button senescence (%)	Granulation		Rind color (a*/b*)	Soluble solids (°Brix)
					Slight (%)	Severe (%)		
'Ponkan'	2	Common	0	0	0	0	0.66	10.2
		Cave	0	0	0	0	0.66	10.2
		Refrigerated	0	0	0	0	0.66	10.2
	3	Common	2.5	2.5	5.0	0	0.69	9.9
		Cave	0	0	2.5	0	0.68	10.0
		Refrigerated	1.3	2.5	5.0	0	0.68	9.9
'Tankan'	3	Common	0	0	21.6	2.3	0.61	9.2
		Cave	0	0	18.2	1.1	0.63	9.2
		Refrigerated	0	0	11.4	2.3	0.63	9.3
	4	Common	0	3.4	25.0	12.5	0.62	8.8
		Cave	1.1	1.1	20.5	6.8	0.64	8.7
		Refrigerated	0	3.4	23.9	7.9	0.67	8.8

[1] Means of 4 tree-replicates, 20 fruits per replicate for 'Ponkan' and 22 fruits per replicate for 'Tankan'. Data of 2008-2009 storage season.

Table 4. Differences in the development of storage disorders of 'Liucheng' orange stored in 3 types of storage facilities.[1]

Duration of storage (months)	Type of storage	Decay (%)	Button disorder (%)	Mesocarp breakdown and other visible disorders (%)	Total (%)
4	Common	2.66	2.04	—	4.70
	Cave	1.47	0.84	—	2.31
	Refrigerated	2.10	0.21	—	2.31
5	Cave	8.54	5.83	1.67	16.04
	Refrigerated	4.34	1.24	1.86	7.44

[1] Means of 4 replicates, 1 box per replicate. Each box had 476 to 489 fruits. Data of 2009-2010 storage season.

When small samples of fruits were used in storage tests, every piece of fruit was carefully handled, and every storage container, being trays or boxes in our studies, were well exposed and well ventilated in the storage. Besides, the storage spaces were mostly empty. But in commercial storage, fruit boxes are more tightly stacked and the storage spaces are fully filled. Therefore, the results of small sample storage and large volume commercial storage may be different. We shall conduct larger scale storage tests to verify our small sample experiment results in the future. Nevertheless, preliminary studies suggested that common storage might be adequate for short-term storage while cave storage might be needed for longer terms and refrigerated storage for the longest terms of storage. Varietal differences in response to storage types may exist also.

Considerations for Costs and Energy Use of the Three Storage Methods

Common storage requires rather simple structures and is easy to build. It’s building cost shall be lower than that of other two types of storage facilities. Since the storage is cooled by ventilating natural cool air, electric energy use shall be minimal. Common storage facilities are convenient for use and easy to operate.

The construction cost of cave storage would be fairly high if a thick layer of concrete liner is used. Such liner is necessary in a place like Taiwan where heavy rains and earthquakes are quite common. Once constructed, the structure is durable and requires little maintenance and repair costs, however. Well constructed cave storage facilities can be used for decades or even centuries if without natural or man-made destructive disasters. Cave storage may or may not have ventilation or exhaust fans. Even if fans are used, electric energy use shall be low. Since the cave must be narrow and elongated in shape, it is not convenient for loading and unloading fruits in the storage operation. Therefore, it may not suit for very large volumes of fruit storage.

Refrigerated storage facilities require sufficiently effective insulation and refrigeration machines and equipment. The initial construction cost should be the highest among the three types of storage facilities. The facilities also needs periodical maintenance services and even repairs only professionals can perform. The storage is cooled by mechanical refrigeration which requires a lot of electric energy. In general, the higher ambient temperature the more energy consumption; and the poorer insulation the more energy waste.

Among all three types of storage methods, refrigeration storage has the highest construction as well as maintenance costs and the highest energy use. Cave storage has high construction costs but low maintenance cost and low energy use, while common storage has the lowest costs and lowest energy use.

More Thoughts Concerning Commercial Storage

When selecting a storage method for commercial fruit storage, both technological and economic factors have to be considered. Whenever possible, environment friendliness of the method should also be considered. We therefore should use all of our knowledge about the requirements of the fruits, available technologies, economic feasibilities, and the environment to make a judicious choice.

Storing fruits in cooler locations

In citrus fruit storage under sub-tropical climate, cooling and maintaining coolness in the storage are usually desirable or even necessary processes. It would be wise, therefore, to select cooler locations to store fruits if economically feasible. The cooler the climate, the better chance to utilize cool ambient air in storage. Cooler ambient air also helps reducing the cost of refrigeration when refrigeration is used. That is because less heat energy to be transferred into the storage by means of conduction and convection and therefore less heat energy to be transferred out of the storage by mechanical means.

Most of our ‘Ponkan’ mandarins are grown in the central and southern Taiwan, and most of our ‘Liucheng’ oranges are grown in the southern Taiwan. During the storage seasons (i.e., winter and spring) of these citrus fruits, the ambient air temperature is much lower in northern Taiwan than in the central or southern Taiwan. For instance, when three spots of interest are compared, Miaoli has significantly lower temperatures than Chiayi which in turn has significantly lower temperatures than Tainan (Fig. 9). Miaoli is located in the north and is the place where our experimental cave and common storage facilities are located. Both Chiayi and Tainan are located in the south and are the places where lots of mandarins and oranges are grown. The farthest distance between any two spots of the three is >150 km. When considering other factors, more than half of the population of the main island of Taiwan resides in the northern part and the main south to north highways and railways pass through Miaoli. Wouldn’t it be wise to store at least part of southern grown citrus fruits in appropriate places like Miaoli in the north? This is a good example for studies on selecting cooler places for citrus storage.

Uses of various storage methods in combination

Common storage has virtues of being low cost and environment friendly. Cave storage is also environment friendly but is more costly and more difficult to build and less convenient to use. Refrigerated storage is most costly among the three storage methods, and it also requires a lot of electric energy consumption which is considered environment unfriendly. Therefore, while selecting a storage method for a predictable lot of fruits, common storage should be considered first followed by cave and refrigerated storage provided that satisfactory storage conditions for the lot of fruits can be met.

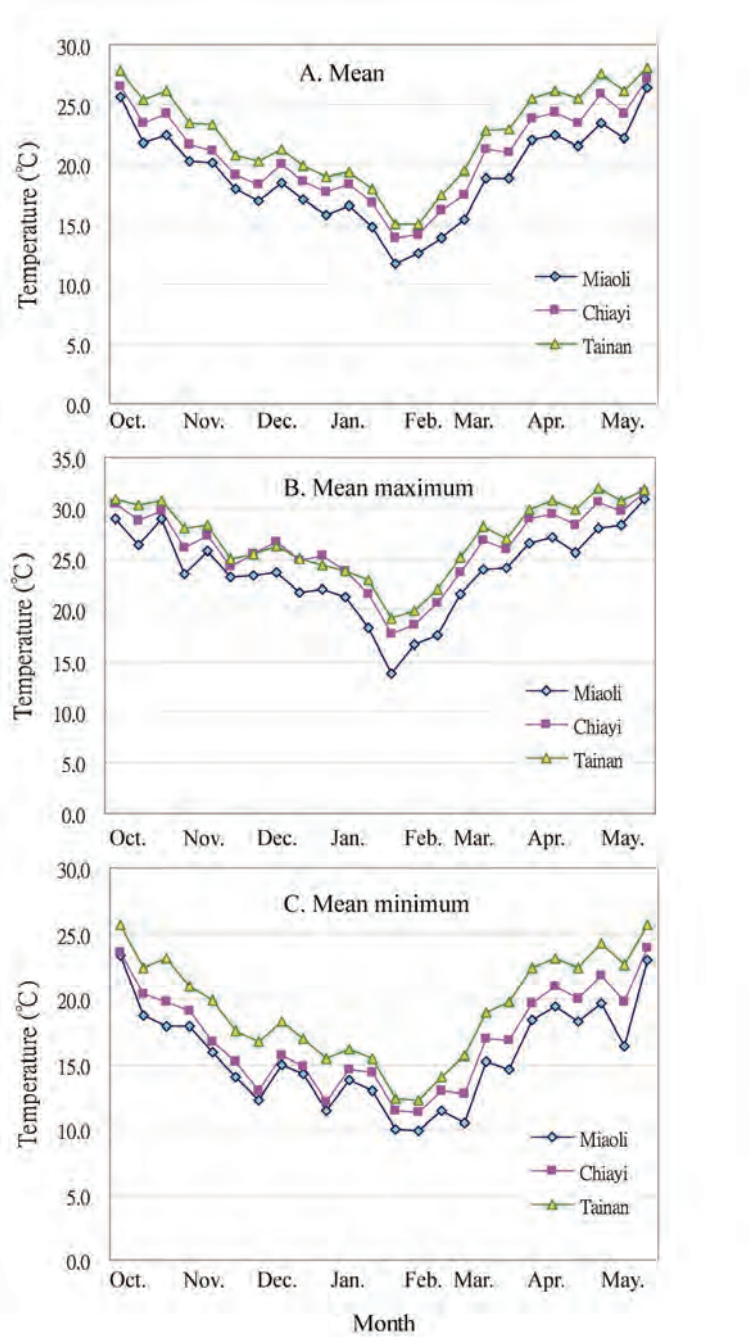

Fig. 9. Comparison of ambient temperatures of Miaoli (—◇—◇—), Chiayi (—■—■—) and Tainan (—△—△—) in the citrus harvesting and storage season of 2007-2008. Based on data published by Taiwan Weather Bureau.

According to our research results and field observations, ‘Ponkan’ mandarins and ‘Tankan’ tangors grown in the northern part of Taiwan may be stored in common storage in the north for 1 to 3 months without severe losses. Cave storage or refrigerated storage may be used for longer periods of storage in order to maintain better fruit quality and to minimize storage disorders. Common storage in the southern region is less useful for lack of cool ambient air in the region. Building cave storage in the south may not be advisable either for the same reason. Therefore, southern grown citrus fruits may be stored in common storage in the south for only a short period (1 to 2 months). The fruits may be shipped to the north and stored in either common storage or cave storage for longer periods (2 to 4 months), however. Refrigerated storage can, of course, be built in any region, but is needed only for long terms (4 to 5 months) of storage for Taiwan citrus. Refrigeration cost would be lower in the north than in the south due to lower ambient temperatures in the former. A good combination of three types of storage facilities, particularly when built in cooler locations, will save money and energy while providing adequate protection for citrus fruits.

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Best Practices for Efficient Postharvest Management of Fruits and Vegetables for Higher Value Addition and Profitability

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Introduction

The post-harvest or post-production operations of agricultural and horticultural products include a wide range of functions between production and consumption. These functions have to be carried out efficiently by different agencies/ individuals in the post-harvest chain in order to supply food of good quality to keep transaction costs low and to deliver high quality and safe raw material for further processing and value addition. Post-harvest operations deserve high priority since they contribute in several ways to the overall goal of sustainable development in agriculture and impact on its profitability. A substantial part of the consumer price for agricultural products, depending on the commodity, the type of post-harvest operation and the organizational structure, is attributable to processing, marketing, transport, storage and handling of the raw product. A considerable part of post-production activities is actually or may be potentially fulfilled on-farm by members of farm households. This adds to the value of the farm product and therefore the income of the household. Women and weaker sections with little access to resources can find income opportunities in handling, processing and trading agricultural products. Especially in rural areas, post-harvest operations contribute to employment, income generation and alleviation of poverty for these groups. Minimal processing has opened new avenues for handsome returns in the production catchments.

There is a pressing need to establish efficient, time-cost-energy saving post-harvest technology systems, which reduce losses and optimize produce suitability and quality for market requirements. Among the critical areas that urgently require attention are: loss minimization, handling production surpluses, safe transport, transit or longer time storage, market access and creating favourable conditions for higher acceptance of high quality and competitively priced processed food. Post-harvest losses remain unacceptably high ranging from 10 to 35 per cent of the perishable commodities produced. As per recent estimate, post-harvest losses in fruits and vegetables are $ 5 billion annually. The Green Revolution was followed by Golden Revolution which led to the large scale production of fruits and vegetables which need to be consumed, stored or exported, requiring additional technological input and infrastructure support. Export markets have become more competitive and discriminating, leading to increased emphasis on quality assurance and food safety. There is increasing shift in the consumption of fruits and vegetables in

Indian diet besides dairy products, fish and meat as sources of vitamin, mineral and protein, requiring newer and effective post-harvest technologies. This can create a win-win situation for producers, processors and consumers.

The global consumer demand for high-quality foods that are fresh, tasty and nutritious has created considerable interest and investment in the development of new or improved post-harvest handling and storage and food-processing technologies and practices. The competitive struggle for markets, which has resulted from more liberalised trade regimes, requires a much greater emphasis on efficient and effective post-harvest handling, processing and distribution to access domestic and global markets. Traditional post-harvest food-processing technologies such as freezing and canning etc are no longer at the forefront of consumer demand.

Indian Scenario on Fruits and Vegetables

India is the fruit and vegetable basket of the world. Being a home of wide variety of fruits and vegetables, it holds a unique position in production figures among other countries. Over 90% of India's exports in fresh products goes to West Asia and East European markets. However, the current level of processing being very low (around 5 per cent as against 70-80 per cent in some East Asian countries), India needs to quickly augment its food and processing at a mega scale.

The covered area under the fresh fruits in India was 5,510,000 ha with the production of 58,740,000 MT in 2005-06. The major fruits grown in India are: mango, grape, apple, apricots, orange, banana , avocados, guava, litchi, papaya, sapota and melons. This is due to its potential in different agro climatic zones. India's export of fresh fruits has increased from US$ million 50.98 in 2005-06 to US$ million 56.88 in 2006-07.

Total vegetable production in India before independence was 15 million tonnes and since Independence for decades the growth rate was stabilized around 0.5%. The impetus on vegetable research and policy intervention to promote vegetable crops witnessed a sudden spurt in growth rate of 2.5%, a hike of five times during the last decade. Major vegetables grown in India are: potato, onion, tomato, cauliflower, cabbage, bean, brinjal, cucumber and gherkin, field and frozen peas, garlic and okra.

The potential technological interventions with improved gene pool and precise management can take growth rate to nearly 6% per annum. The area under vegetables increased from 5.59 million ha in 1991–92 to 6.76 million ha during 2004–05. The production in this period increased from 58.53 million tonnes to 101.43 million tonnes. During the period, productivity of vegetables increased from 10.5 tonne/ha to 15.0 tonne/ha. While West Bengal continues to be the leading State in area and production, the productivity is higher in Tamil Nadu, followed by Uttar Pradesh and Bihar.

India's exports of fresh fruit and vegetable has increased from US$ 374.68 million in 2005-06 to US$ 534.97 million in 2006-07.

India ranks fifth in the world in cropped area under cultivation and production of potatoes. India produces 41% of world's mangoes, 23% bananas, 24% cashew nuts, 36% green peas and 10% onion. The total export value of the main exporting fruit crop from India is mango. Exports of mangoes, grapes, and mushrooms have started going to the United Kingdom, Middle East, Singapore and Hong Kong. Among vegetable, onion occupies first position, potatoes and green vegetables like okra, bitter gourd, green chillies have good export potential (Table 1).

India is the 2nd largest onion growing country in the world. Indian onions are famous worldwide for their pungency. The Gulf countries are the main importers of the onion bulb, and neighbouring Pakistan and China are India's main competitors in the global market. India's export of onion has increased from USD million 159.96 in 2005-06 to USD million 258.05 in 2006-07. Bangladesh, Malaysia, Sri Lanka, U.A.E, Pakistan and Nepal are the major markets of Indian Onion.

Mango, called the king of fruits in India, accounts for 40 percent of the national fruit production of 22.168 million tonnes a year. It occupies 42 percent of the country's 24.87 million hectares land under fruit cultivation. India exported 79,060.88 MT of fresh mangoes with the value of USD million 31.48 in 2006-07. The major markets for Indian mangoes are U.A.E, Bangladesh, U.K, Saudi Arabia and Nepal. India is estimated to account for about 60 percent (9.5 million tonnes) of the world's mango production of 15.7 million tonnes.

Table 1. Area and production of major horticultural crops (2008-09).

Crops	Area '000 ha	Production '000 tonnes
I. Fruits		
Mango	2309	12831
Apple	271	1985
Banana	708	27119
Citrus	926	8526
Guava	207	2330
Grapes	69	1764
Papaya	98	3641
Pineapple	84	1354
Total	**66106**	**69453**
II. Vegetables		
Potato	1824	36284
Onion	836	13792
Tomato	608	11328
Brinjal	602	10420
Cabbage	308	6805
Cauliflower	358	6566
Peas	349	2914
Okra	436	4524
Total	**8204**	**133071**

(Source: Horticulture Division, Ministry of Agriculture, Govt. of India, 2008)

The horticulture and allied sector is an integral element for food and nutritional security in the country. Horticulture is the main segment, while its various sub-segments are fruits, vegetables, aromatic and herbal plants, flowers, spices and plantation crops. All these are regarded as the essential ingredients of economic security. The wide range of agro-climatic conditions of India is conducive for growing a large variety of horticultural crops, including root and tuber crops, mushroom, ornamental crops, and plantation crops like coconut, areca nut, cashew and cocoa.

The Government of India has recognized horticulture crops as a means of diversification in agriculture in an eco-friendly manner through efficient use of land and optimum utilization of natural resources. Horticulture seeks to create ample opportunities for employment, particularly for unemployed youths and women folk. India has maintained leadership in the production of many commodities like mango, banana, acid lime, coconut, areca nut, cashew, ginger, turmeric and black pepper. Presently, it is the second largest producer of fruits and vegetables in the world.

India is next only to China in area and production of vegetables and occupies prime position in the production of cauliflower, second in onions and third in cabbage in the world. India has also made noticeable advancement in the production of flowers. Further, it is the largest producer, consumer and exporter of spices. India is home to a wide variety of spices like black pepper, cardamom (small and large), ginger, garlic, turmeric, chilli and a large variety of tree and seed spices. Almost all the States in the country grow one or more spices. The major spice producing States are Andhra Pradesh, Tamil Nadu, Orissa and Madhya Pradesh. North Eastern region and Andaman and Nicobar Islands also have potential areas cultivated for spices, particularly organically.

Post-harvest Management Procedures that are Critical to Maintaining the Quality and Safety of Horticultural Crops

Liberalization of trade in agriculture has provided newer opportunities to the farm sector to access markets of agricultural commodities worldwide. To benefit small and marginal farmers, who predominate country’s economy, there is a need to strengthen post-harvest management system, encompassing all areas from production to final sale-quality standards, processing, storage, transport, and warehousing.

1. Production Practices

Production practices have a tremendous effect on the quality of fruits and vegetables at harvest and on postharvest quality and shelf life. To start with, it is well known that some cultivars ship better and have a longer shelf life than others. In addition, environmental factors such as soil type, temperature, frost, and rainy weather at harvest can have an adverse effect on storage life and quality. For example, carrots grown on muck soils do not hold up as well in storage as carrots grown on lighter, upland soils. Lettuce harvested during a period of rain does not ship well and product losses are increased.

Management practices can also affect post-harvest quality. Produce that has been stressed by too much or too little water, high rates of nitrogen, or mechanical injury (e.g., scrapes, bruises, abrasions) is particularly susceptible to post-harvest diseases. Mould and decay on winter squash, caused by the fungus, result from the fruits lying on the ground, and can be alleviated by using mulch. Broccoli heads are susceptible to postharvest rot caused by the bacteria Erwinia if nitrogen is applied as foliar feed, a grower should feed the soil, not the leaves. Beets and radishes are susceptible to soil-borne diseases when the soil temperature reaches 25-26℃; symptoms are black spots on these root crops.

Food safety also begins in the field, and should be of special concern, since a number of outbreaks of food-borne illnesses have been traced to contamination of produce in the field. Common-sense prevention measure include a number of don'ts:

- Don't apply raw dairy or chicken manure or slurries to a field where a vegetable crop such as leafy lettuce is growing;
- Don't apply manure to an area immediately adjacent to a field nearing harvest maturity;
- Don't forget to clean equipment that has been used to apply manure to one field before moving it to another field in production;
- Don't irrigate with water from a farm pond used by livestock;
- Don't harvest fruit from the orchard floor for human consumption as whole fruit or non-pasteurised juices, especially if manure has been spread or animals allowed to graze;
- Don't accumulate harvested product in areas where birds roost.

A grower *should* constantly evaluate water used for irrigation, and compost all animal manures before applying them to fields. There are many good sources of information on growing conditions and production practices that promote post-harvest quality. Consult textbooks, extension publications, and trade journals, and become involved with grower organizations to find our more.

2. Harvest Handling

Quality cannot be improved after harvest, only maintained; therefore it is important to harvest fruits and vegetables at the proper stages and size and at peak quality. Immature or over -mature produce may not last as long in storage as that picked at proper maturity. Horticulture Institutes of Indian Council of Agricultural Research (ICAR), Directorates of Extension of Agricultural Universities and State Departments of Agriculture publications, websites and call centres are excellent source of information on harvest maturity indicators for vegetables and fruits.

Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept shaded in the field. Handle produce gently. Crops destined for storage should be free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms as well.

Post-harvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400% by a single bad bruise on an apple, and skinned potatoes may lose three to four times as much as weight as non-skinned potatoes. Damage can be prevented by training harvest labour to handle the crop gently; harvesting at proper maturity; harvesting dry whenever possible; handling each fruit or vegetable no more than necessary (field pack if possible); installing padding inside bulk bins; and avoiding over or under-packing of containers.

3. Packing and Packaging of Fruits and Vegetables

Preparation of produce for market may be done either in the field or at the packing house. This involves cleaning, sanitizing, and sorting according to quality and size, waxing and where appropriate, treatment with an approved fungicide prior to packing into shipping containers, Packaging protects the produce from mechanical injury, and contamination during marketing.

Corrugated fibreboard containers are commonly used for the packaging of produce, although reusable plastic containers can be used for that purpose. Packaging accessories such as trays, cups, wraps, liners, and pads may be used to help immobilize the produce within the packaging container while serving the purpose of facilitating moisture retention, chemical treatment and ethylene absorption. Either hand-packing or mechanical packing systems may be used. Packing and packaging methods can greatly influence air flow rates around the commodity, thereby affecting temperature and relative humidity management of produce while in storage or in transit.

4. Temperature and Relative Humidity Management

Temperature is the most important environmental factor that influences the deterioration of harvested commodities. Most perishable horticultural commodities have an optimal shelf-life at temperatures of approximately 0℃. The rate of deterioration of perishables however increases two to three fold with every 10°C increase in temperature. Temperature has a significant effect on how other internal and external factors influence the commodity, and dramatically affects spore germination and the growth of pathogens.

i) Effect of temperature on the deterioration rate of a non-chilling sensitive commodity

Temperature (°C)	Assumed Q_{10}*	Relative rate of deterioration	Relative post-harvest life	Loss per day (%)
0	-	1.0	100	1
10	3.0	3.0	33	3
20	2.5	7.5	13	8
30	2.0	15.0	7	14
40	1.5	22.5	4	25

$$*Q_{10} = \frac{\text{Rate of deterioration at temperature T } +10℃}{\text{Rate of deterioration at temperature T}}$$

ii) Effect of temperature on the deterioration rate of a chilling sensitive commodity

Temperatures either above or below the optimal range for fresh produce can cause rapid deterioration due to the following disorders:

Freezing: Perishable commodities are generally high in water content, and possess large, highly vacuolated cells. The freezing point of their tissues is relatively high (ranging from -3°C to -0.5°C), and disruption caused by freezing generally results in immediate collapse of their tissues and a total loss of cellular integrity. Freezing occurs in cold storage systems either due to inadequate refrigerator design, or to thermostat failure. Freezing can also occur upon exposure to inclement weather conditions as occurs when produce is allowed to remain for even short periods of time on unprotected transportation docks during winter.

Chilling injury: Some commodities (chiefly those native to the tropics and subtropics) respond unfavourably to storage at low temperatures which are well above their freezing points, but below a critical temperature termed their chilling threshold temperature or lowest safe temperature. Chilling injury is manifested in a variety of symptoms including surface and internal discoloration, pitting, water soaking, failure to ripen, uneven ripening, development of off flavours and heightened susceptibility of pathogen attack.

Lowest safe temperature (℃)	Commodity
3	Asparagus, cranberry, jujube
4	Cantaloupe, certain apple cultivars (such as McIntosh and Yellow Newton), certain avocado cultivars, litchi, potato
5	Cactus pear, cowpeas, guava, lima bean, mandarin, orange,
7	Certain avocado cultivars, okra, olive, pepper, pineapple, pomegranate, snap bean
10	Carambola, cucumber, brinjal, grapefruit, lime, mango (ripe), melons, papaya, passion fruit, plantain, rambutan, squash(soft rind), taro, tomato (ripe), watermelon
13	Banana, breadfruit, ginger, jackfruits, lemon, mango(mature-green), mangosteen, pumpkin and hard rind squash, sapota, sweet potato, tomato(mature-green), yam

5. Classification of Heating/Chilling-Sensitive Fruits and Vegetables According to Their Lowest Safe Temperature for Transport and Storage

Heat injury: High temperature conditions are also injurious to perishable crops. Transpiration is vital to maintaining optimal growth temperatures in growing plants. Organs removed from the plant, however, lack the protective effects of transpiration, and direct sources of

heat, such as sunlight, can rapidly elevate the temperature of tissues to above the thermal death point of their cells, leading to localized bleaching, necrosis (sunburn or sunscald) or general collapse.

Relative humidity (RH) Relative humidity is defined as the moisture content (as water vapour) of the atmosphere, expressed as a percentage of the amount of moisture that can be retained by the atmosphere (moisture holding capacity) at a given temperature and pressure without condensation. The moisture holding capacity of air increases with temperature. Water loss is directly proportional to the vapour pressure difference (VPD) between the commodity and its environment. VPD is inversely related to the RH of the air surrounding the commodity.

RH can influence water loss, decay development, the incidence of some physiological disorders, and uniformity of fruit ripening. Condensation of moisture on the commodity (sweating) over long periods of time is probably more important in enhancing decay than is the RH of ambient air. An appropriate RH range for storage of fruits is 85 to 95 percent while that for most vegetables varies between 90 and 98 percent. The optimal RH range for dry onions and pumpkins is 70 to 75 percent. Some root vegetables, such as carrot, parsnip, and radish, can best be held at 95 to 100 percent RH.

RH can be controlled by one or more of the following procedures:

1. adding moisture (water mist or spray, steam) to air with the use of humidifiers;
2. regulating air movement and ventilation in relation to the produce load in the cold storage room;
3. maintaining the temperature of the refrigeration coils in the storage rooms or transit vehicle to within about 1°C of the air temperature;
4. providing moisture barriers that insulate walls of storage rooms and transit vehicles;
5. adding polyethylene liners in packing containers and using perforated polymeric films for packaging;
6. wetting floors in storage rooms;
7. adding crushed ice in shipping containers or in retail displays for commodities that are not injured by the practice; and
8. sprinkling produce with sanitized, clean water during retail marketing of commodities that benefit from misting, such as leafy vegetables, cool season root vegetables, and immature fruit vegetables (such as snap beans, peas, sweet corn, and summer squash).

Post-harvest Treatments Designed to Minimize Produce Contamination and to Maximize Quality

1. Pre-cooling

Pre-cooling is the first step in good temperature management. The *field heat* of a freshly harvested crop-heat the product holds from the sun and ambient temperature- is usually high, and

should be removed as quickly as possible before shipping, processing, or storage. Refrigerated trucks are not designed to cool fresh commodities but only maintain the temperature of pre-cooled produce. Likewise, most refrigerated storage rooms have neither the refrigeration capacity nor the air movement needed for rapid cooling. Therefore, pre-cooling is generally a separate operation requiring special equipment and/or rooms.

Rapid pre-cooing to the product's lowest safe temperature is most critical for crops with inherently high respiration rates. These include artichokes, Brussels sprouts, cut flowers, green onions, snap beans, asparagus, broccoli, mushrooms, peas and sweet corn. Crops with low respiration rates include nuts, apples, grapes,garlic, onions, potatoes(mature), and sweet potatoes.

Appropriate pre-cooling methods as well as appropriate storage temperature and humidity for a number of fruits and vegetables. The following methods are the most commonly used:

Room cooling: Produce is placed in an insulated room equipped with refrigeration units. This method can be used with most commodities, but is slow compared with other options. A room used only to store previously cooled produce requires a relatively small refrigeration unit. However, if it is used to cool produce, a larger unit is needed. Containers should be stacked so that cold air can move around them, and constructed so that it can move through them. Used refrigerated truck bodies make excellent small cooling rooms.

Forced-air cooling: Fans are used in conjunction with a cooling room to pull cool air through packages of produce. Although the cooling rate depends on the air temperature and the rate of air flow, this method is usually 75-90% faster than room cooling. Fans should be equipped with a thermostat that automatically shuts them off as soon as the desired product temperature is reached.

Hydro-cooling: Dumping produce into cold water, or running cold water over produce, is an efficient way to remove heat, and can serve as a means of cleaning at the same time. In addition, hydro-cooling reduces water loss and wilting. Use of a disinfectant in the water is recommended to reduce the spread of diseases. Hydro-cooling is not appropriate for berries, potatoes to be stored, sweet potatoes, bulb onions, garlic, or other commodities that cannot tolerate wetting.

Water removes heat about five times faster than air, but is less energy efficient. Well water is a good option, as it usually comes out of the ground with temperatures in the 10-15°C range. Mechanical refrigeration is the most efficient method for cooling water. A thermal storage immersion hydro-cooler system can be fabricated economically to suit various volume requirements. Used stainless-steel bulk farm milk coolers may be an option. If hydro-cooling water is recirculated, it should be chlorinated to minimize disease problems.

A study compared sweet corn quality after hydro-cooling with ice water, well water cooling and refrigerated air cooling, and subsequent refrigerated storage. Hydro-cooling with ice water

lowered the temperature of the ears most quickly. Well water cooling followed by refrigerated storage appeared to offer no advantage over refrigerated storage immediately after harvest.

Top or liquid icing: Icing is particularly effective on dense products and palletized packages that are difficult to cool with forced air. In top icing, crushed ice is added to the container over the top of the produce by hand or machine. For liquid icing, a slurry of water and ice is injected into produce packages through vents or handholds without removing the packages from pallets and opening their tops. Icing methods work well with high-respiration commodities such as sweet corn and broccoli. One pound of ice will cool about three pounds of produce from 85 °F to 40 °F.

Vacuum cooling: Produce is enclosed in a chamber in which a vacuum is created. As the vacuum pressure increases, water within the plant evaporates and removes heat from the tissues. This system works best for leafy crops, such as lettuce, which have a high surface-to volume ratio. To reduce water loss, water is sometimes sprayed on the produce prior to placing it in the chamber. This process is called hydrovac cooling. The primary drawback to this method is the cost of the vacuum chamber system.

Temperature management is the most effective tool for extending the shelf life of fresh horticultural commodities. It begins with the rapid removal of field heat by using one of the cooling methods.

Variable	Cooling method				
	Ice	Hydro	Vacuum	Forced-air	Room
Cooling time (h)	0.1-0.3	0.1-1.0	0.3-2.0	1.0-10.0	20-100
Water contact with the product	Yes	Yes	No	No	No
Product moisture loss (%)	0-0.5	0-0.5	2.0-4.0	0.1-2.0	0.1-2.0
Capital cost	High	low	medium	low	low
Energy efficiency	low	High	High	low	low

2. Comparison of Methods Used for Cooling

Packing fresh produce with crushed or flaked ice provides rapid cooling, and can provide a source of cooling and high RH during subsequent handling. The use of crushed ice is, however, limited to produce that is tolerant to direct contact with ice and packaged in moisture-resistant containers.

Clean, sanitized water is used as the cooling medium for the hydro-cooling (shower or immersion systems) of commodities that tolerate water contact and are packaged in moisture-resistant containers. Vacuum cooling is generally applied to leafy vegetables that release water vapour quickly, thereby allowing them to be rapidly cooled. During forced-air cooling on the other hand, refrigerated air is forced through produce packed in boxes or pallet bins. Forced-air cooling is applicable to most horticultural perishables.

Precise temperature and RH management are required to provide the optimum environment for fresh fruits and vegetables during cooling and storage. Precision temperature management (PTM) tools, including time-temperature monitors, are increasingly being employed in cooling and storage facilities.

3. Refrigerated Transport and Storage

It retards the following elements of deterioration in perishable crops:

- Aging due to ripening, softening, and textural and colour changes;
- Undesirable metabolic changes and respiratory heat production;
- Moisture loss and the wilting that results;
- Spoilage due to invasion by bacteria, fungi, and yeasts; and
- Undesirable growth, such as sprouting of potatoes.

One of the most important functions of refrigeration is to control the crop's respiration rate. Respiration generates heat as sugars, fats and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavour, loss of saleable weight, and more rapid deterioration. The respiration rate of a product strongly determines its transit and postharvest life. The higher the storage temperature, the higher the respiration rate will be

For refrigeration to be effective in postponing deterioration, it is important that the temperature in cold storage rooms be kept as constant as possible. The optimum temperature ranges for various crops. Exposure to alternating cold and warm temperatures may result in moisture accumulation on the surface of produce (sweating), which may hasten decay. Storage rooms should be well insulated and adequately refrigerated, and should allow for air circulation to prevent temperature variation. Be sure that thermometers, thermostats, and manual temperature controls are of high quality, and check them periodically for accuracy.

On-farm cooling facilities are a valuable asset for any produce operation. A grower who can cool and store produce has greater market flexibility because the need to market immediately after harvest is eliminated. The challenge, especially for small-scale producers, is the set-up cost. Innovative farmers and researchers have created a number of designs for low-cost structures.

Cold storage facilities should be appropriately designed, of good construction, and be adequately equipped. Their insulation should include a complete vapour barrier on the warm side of the insulation; sturdy floors; adequate and well-positioned doors for loading and unloading; effective distribution of refrigerated air; sensitive and properly located controls; refrigerated coil surfaces designed to adequately minimize differences between the coil and air temperatures; and adequate capacity for expected needs. Commodities should be stacked in the cold room or the

refrigerated vehicle with air spaces between pallets and room walls so as to ensure proper air circulation. Storage rooms should not be loaded beyond their capacity limit if proper cooling is to be achieved. Commodity temperature rather than air temperature should be measured in these facilities.

Temperature management during transportation of fresh fruits and vegetables over long distances is critical. Loads must be stacked so as to enable proper air circulation, in order to facilitate removal of heat from the produce as well as to dissipate incoming heat from the atmosphere and off the road. Stacking of loads must also incorporate consideration for minimizing mechanical damage. Transit vehicles must be cooled prior to loading the fresh produce. Delays between cooling after harvest and loading into transit vehicles should also be avoided. Proper temperature maintenance should be ensured throughout the handling system.

As far as possible, environmental conditions (temperature; relative humidity; concentrations of oxygen, carbon dioxide and ethylene) should be optimized in transport vehicles. Treatment with ethylene to initiate ripening during transportation is feasible, and is commercially used to a limited extent on mature green bananas and tomatoes. Produce should be cooled prior to loading and should be loaded with an air space between the palletized product and the walls of the transport vehicles in order to facilitate temperature control. Vibration during transportation should be minimized, so as to avoid damage due to bruising. Controlled-atmosphere and precision temperature management should, where possible, be observed so as to allow non-chemical insect control for markets which possess quarantine restrictions against pests endemic to exporting countries and for markets that do not want their produce exposed to chemical fumigants.

Mixing several produce items in one load is common and often compromises have to be made in selecting an optimal temperature and atmospheric composition when transporting chilling-sensitive with non-chilling sensitive commodities. In the latter case, ethylene scrubbers can be used to remove ethylene from the circulating air within the vehicle. Several types of insulating pallet covers are available for protecting chilling-sensitive commodities when transported with non-chilling-sensitive commodities at temperatures below their threshold chilling temperatures.

3.1 Maintaining the cold chain for perishables

Harvest	- Minimize delays before cooling
	- Cool the product thoroughly as soon as possible
Cooling	- Store the product at optimum temperature
Temporary storage	- Practice first in first out rotation
	- Ship to market as soon as possible
Transport to market	- Use refrigerated loading area
	- Cool truck before loading

	- Load pallets towards the centre of the truck
	- Put insulating plastic strips inside door of reefer if truck makes multiple stops
	- Avoid delays during transport
	- Monitor product temperature during transport
Handling at destination	- Use a refrigerated unloading area
	- Measure product temperature
	- Move product quickly to the proper storage area
	- Transport to retail markets or food service operations in refrigerated trucks
	- Display at proper temperature range
Handling at home or food service outlet	- Store product at proper temperature
	- Consume the product as soon as possible

4. Return on Investment in Temperature and Relative Humidity Management

Deficiencies in cold chain management whether due to limitations in refrigeration, improper handling and storage, or inadequate humidity control, can lead to losses in profits as well as in horticultural crops. Overcoming such deficiencies necessitates improvements in methodologies, operations and handling along the chain. Often the level of investment required in overcoming such deficiencies is minimal in comparison to the level of losses sustained over time.

Researches have established that a one-hour delay in cooling strawberries after harvest resulted in a 10 percent loss due to decay during marketing. The resulting economic loss exceeded the increased cost of expedited handling of the strawberries by more frequent deliveries of harvested fruit to the cooling facility and initiation of forced-air cooling. Similarly, another study showed that poor temperature management of lettuce resulted in a net income loss of US$172.50 per truck-load of 900 cartons.

Chilling injury

Many vegetables and fruits store best at temperatures just above freezing, while others are injured by low temperatures and will store best at 45 to 55 degrees F. Both time and temperature are involved in chilling injury. Damage may occur in a short time if temperatures are considerably below the danger threshold, but some crops can withstand temperatures a few degrees into the danger zone for a longer time. The effects of chilling injury are cumulative in some crops. Low temperatures in transit, or even in the field shortly before harvest, add to the total effects of chilling that might occur in storage.

Crops such as basil, cucumbers, eggplants, pumpkins, summer squash, okra, and sweet potatoes are highly sensitive to chilling injury. Moderately sensitive crops are snap beans, muskmelons, peppers, winter squash, tomatoes, and watermelons. These crops may look sound when removed from low temperature storage, but after a few days of warmer temperatures, chilling symptoms become evident: pitting or other skin blemishes, internal discoloration, or failure to ripen. Tomatoes, squash, and peppers that have been over-chilled may be particularly susceptible to decay such as *Alternaria rot.*

Preventing moisture loss

While temperature is the primary concern in the storage of fruits and vegetables, relative humidity is also important. The relative humidity of the storage unit directly influences water loss can severely degrade quality-for instance, wilted greens may require excessive trimming, and grapes may shatter loose from clusters if their stems dry out. Water loss means saleable weight loss and reduced profit.

Most fruit and vegetable crops retain better quality at high relative humidity (80to 95%) but at this humidity, disease growth is encourages. The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required. Maintaining high relative humidity in storage is complicated by the fact that refrigeration removes moisture. Humidification devices such as spinning disc aspirators may be used. Even buckets of water will increase humidity as the fans blow air across the water's surface and increase evaporation. Keeping the floor wet is helpful, though messy and potentially hazardous to two-legged creatures; frequent cleansing with a weak chlorine solution will be needed to prevent harbouring of disease organisms in water and produce scraps on the floor. Crops that can tolerate direct contact with water may be sprinkled to promote high relative humidity.

Treatments

1. Treatments to Reduce Microbial Contamination

Over the past few years, food safety has become and continues to be the number one concern of the fresh produce industry. A "Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables," was published by the U.S. Food and Drug Administration in October 1998. This Guide is based on the following principles:

1) Prevention of microbial contamination of fresh produce is favoured over reliance on corrective actions once contamination has occurred;
2) In order to minimize microbial food safety hazards in fresh produce, growers, packers, or shippers should use good agricultural and management practices in those areas over which they have control;

3) Fresh produce can become microbiologically contaminated at any point along the farm-to-table food chain. Human and /or animal faeces are the source of microbial contamination of fresh produce;
4) Whenever water comes in contact with produce, its quality dictates the potential for contamination. The potential of microbial contamination from water used with fresh fruits and vegetables must be minimized;
5) The use of animal manure or municipal bio-solid wastes as fertilizers should be closely managed in order to minimize the potential for microbial contamination of fresh produce; and
6) Worker hygiene and sanitation practices during production, harvest, sorting, packing, and transport play a critical role in minimizing the potential for microbial contamination of fresh produce.

Clean water containing an appropriate concentration of sanitizers is required in order to minimize the potential transmission of pathogens from water to produce, from healthy to infected produce within a single lot, and from one lot of produce to another, over time (Table 2). Waterborne microorganisms, including post-harvest plant pathogens and agents of human illness, can be rapidly acquired and taken up on plant surfaces. Natural plant surface contours, natural openings, harvest and trimming wounds and scuffing can provide points of entry as well as safe harbour for microbes. When located in these protected sites, microbes are largely unaffected by common or permitted doses of post-harvest water sanitizing treatments. It is therefore essential that the sanitizer concentration is sufficient to kill microbes before they attach or become internalized in produce. The concentration of sanitizer is important in some pre-harvest water uses(such as spraying pesticides or growth regulators) and in all post-harvest procedures involving water, including washing, cooling, water-mediated transport (flumes), and post-harvest drenching with calcium chloride or other chemicals.

2. Treatments to Minimize Water Loss

Transpiration, or evaporation of water from the plant tissues, is one of the major causes of deterioration in fresh horticultural crops after harvest. Water loss through transpiration not only results in direct quantitative losses (loss of saleable weight), but also causes losses in appearance (wilting, shrivelling), textural quality (softening, flaccidity, limpness, loss of crispness and juiciness), and nutritional quality. Transpiration can be controlled either through the direct application of post-harvest treatments to the produce (surface coatings and other moisture barriers) or through manipulation of the environment (maintenance of high relative humidity).

Treatments that can be applied to minimize water loss in fruits and vegetables include:

a) Curing of certain root vegetables, such as garlic, onion, potato, and sweet potato;
b) Waxing and the sue of other surface coatings on commodities, such as apple, citrus fruits, nectarine, peach, plum, pomegranate, and tomato;

c) Packaging in polymeric films that act as moisture barriers;
d) Careful handling to avoid physical injuries, which increase water loss from produce; and
e) Addition of water to those commodities that tolerate misting with water, such as leafy vegetables.

Table 2. Sanitizing chemicals used in produce handling.

Sanitizing chemicals	**Advantages**	**Disadvantages**
Chlorine compounds Calcium hypochlorite Sodium hypochlorite Chlorine gas Chlorine dioxide	Low cost	Corrosive, irritating, trihalomethanes are a by-product
Iodine compounds	Low cost, non irritating	Slightly corrosive, staining
Ozone	Faster action on microorganisms, fewer disinfection by-products than chlorine	Higher cost than chlorine
Peroxyacetic acid, Hydrogen peroxide	More effective in removing and controlling microbial bio films	Higher cost than chlorine

3. Treatments to Reduce Ethylene Damage

The promotion of senescence in harvested horticultural crops by ethylene (1ppm or higher) results in acceleration of deterioration and reduced post-harvest life. Ethylene accelerates chlorophyll degradation and induces yellowing of green tissues, thus reducing the quality of leafy, floral and immature fruit-vegetables and foliage ornamentals. Ethylene induces abscission of leaves and flowers, softening of fruits, and several physiological disorders. Ethylene may increase decay development of some fruits by accelerating their senescence and softening and by inhibiting the formation of antifungal compounds in the host tissue. In some cases, ethylene may stimulate the growth of fungi, such as *Botrytis cineria* on strawberries and *Penicillium italicum* on oranges.

The incidence and severity of ethylene-induced deterioration symptoms is dependent upon temperature, time of exposure, and ethylene concentration. The yellowing of cucumbers can, for example, result from exposure to either 1 ppm ethylene over 2 days or to 5 ppm ethylene over ½ day at 10°C. Ethylene effects are cumulative throughout the post-harvest life of the commodity.

Treatment of ornamental crops with 1-methylcylopropene (1-MCP), which is an ethylene action inhibitor, provides protection against ethylene damage. The commercial use of this product

at concentrations of up to 1 ppm on apples, apricots, avocados, kiwifruit, mangoes, nectarines, papayas, peaches, pears, persimmons, plums, and tomatoes was approved by the United States Environmental Protection Agency. The use of 1-MCP will no doubt be extended to several other fruits and vegetables, and to use in other regions.

4. Treatments for Decay Control

A major cause of losses in perishable crops is the action of a number of microorganisms on the commodity. Fungi and bacteria may infect the plant organ at any time. “Latent” infections, in which fungi invade fruit tissues shortly after flowering, become apparent only at the onset of ripening. Post-harvest rots frequently occur as a result of rough handling during the marketing process and are caused by a wide array of microorganisms. The grey mould *Botrytis cineria* is a very important cause of loss in many commodities (such as grapes, kiwifruit, pomegranates, raspberries, and strawberries), and is an aggressive pathogen, even at low temperatures. Virus infection frequently lowers the quality of perishable commodities, usually as a result of visual deterioration, although viruses may also affect flavour and composition.

Curing is a post-harvest treatment that facilitates certain anatomical and physiological changes that can prolong the storage life of some root crops (Table 3). It is one of the most effective and simple means of reducing water loss and decay during subsequent storage of root, tuber and bulb crops.

Sanitation practices include treatment to reduce populations of microorganisms on equipment, on the commodity, and in the wash water used to clean it. Water washes alone are effective in removing nutrients that allow microorganisms to grow on the surfaces of produce as well as in removing inoculums of post-harvest pathogens. The addition of sanitizers to water dumps and spray or dip washes, reduces inoculums levels for decay-causing organisms from fruit surfaces, inactivates spores brought into solution from fruit or soil and prevents the secondary spread of inoculums in water.

Treatments for decay control include:

- heat treatments, such as dipping mangoes in water at a temperatures of 50 °C, for 5 minutes in order to reduce subsequent development of anthracnose;
- use of post-harvest fungicides, such as imazalil and /or thiabendazole on citrus fruits;
- use of biological control agents alone or in combination with fungicides at lower concentrations on citrus fruits;
- use of growth regulators such as gibberellic acid or 2, 4-D to delay senescence of citrus fruits; and
- use of 15-20 percent CO_2 in air or 5 percent O_2 on strawberries, cane berries, figs, and pomegranates; and (6) use of SO2 fumigation(100 ppm for one hour) on grapes.

Table 3. Conditions for curing root, tuber and bulb crops.

Crop	Temperature (℃)	Relative humidity %	Duration (days)
Tapioca/Cassava root	30-40	90-95	2-5
Onion and garlic bulbs	30-45	60-75	1-4
Potato tubers	15-20	85-90	5-10
Sweet potato roots	30-32	85-90	4-7
Yam tubers	32-40	90-100	1-4

5. Treatment for Insect Control

Fresh fruits, vegetables and flowers may harbour a large number of insects during post-harvest handling. Many of these insect species, in particular fruit flies can seriously disrupt trade among countries. The identification and application of acceptable disinfestations treatments including irradiation will greatly facilitate globalization of trade in fresh produce. Criteria for the selection of the most appropriate disinfestations treatment for a specific commodity include cost, the efficacy of that treatment against insects of concern, safety of the treatment as well as the ability of that treatment to preserve and maintain produce quality.

Currently approved quarantine treatments, other than irradiation, include certification of insect-free areas, use of chemicals (e.g., methyl bromide, phosphine, hydrogen cyanide), cold treatments, heat treatments, and combinations of these treatments, such as methyl bromide fumigation in conjunction with cold treatment. The use of alternative treatments, such as fumigants (carbonyl sulphide, methyl iodide, sulphuryl fluoride) and insecticidal atmospheres (oxygen concentrations of less than 0.5 percent and/or carbon dioxide concentrations ranging between 40 and 60 percent) along or in combination with heat treatments, and ultraviolet radiation, are currently under investigation. These treatments are not, however, broad-spectrum treatments and are potentially phytotoxic when applied to some commodities.

Most insects become sterile when subjected to irradiation doses ranging between 50 and 750 Gy. The actual dosage required to produce sterility in insects varies in accordance with the species concerned and its stage of development. An irradiation dose of 250 Gy was approved by the United States quarantine authorities for application to fresh commodities, such as leeches, mangoes and papayas in light of the efficacy of that dose in preventing the reproduction of tropical fruit flies. Irradiation doses of 250 GY can be tolerated by most fresh fruits and vegetables with minimal detrimental effects on quality. Doses ranging between 250 and 1000 Gy (the maximum irradiation dose allowed as of 2002), can, however, be damaging to some commodities. Fruits, in general, are more tolerant to the expected dose range (250 to 500 Gy absorbed by fruits on the inside vs. those on the outside of the pallet) than non-fruit vegetables and cut flowers.

Detrimental effects of irradiation on fresh produce may include loss of green colour (yellowing), abscission of leaves and petals, tissue discoloration, and uneven ripening. These detrimental effects may not become visible until after the commodity reaches the market. The effects of irradiation must therefore be tested on individual commodities, prior to large scale commercialization of the irradiation treatment.

Post-harvest Treatments Designed to Manipulate the Environment around Produce in Order to Enhance Quality

1. Controlled / Modified Atmosphere (CA/MA) Storage

When used as supplements to keeping fresh horticultural perishables within their optimum ranges of temperature and relative humidity, controlled atmospheres (CA) or modified atmospheres (MA) can serve to extend their post-harvest-life. Optimum oxygen and carbon dioxide concentrations lower respiration and ethylene production rates, reduce ethylene action, delay ripening and senescence, retard the growth of decay-causing pathogens, and control insects. CA conditions which are not suited to a given commodity can, however, induce physiological disorders and enhance susceptibility to decay.

Several refinements in CA storage technology have been made in recent years. These include: the creation of nitrogen-on-demand by separation of nitrogen from compressed air through the use of either molecular sieve beds or membrane systems; use of low (0.7 to 1.5 percent) oxygen concentrations that can be accurately monitored and controlled; rapid establishment of CA, ethylene-free CA, programmed (or sequential) CA (such as storage in 1 percent O_2 for 2 to 6 weeks followed by storage in 2-3 percent O_2 for remainder of the storage period), and dynamic CA where levels of O_2 and CO_2 are modified as needed based on monitoring specific attributes of produce quality, such as ethanol concentration and chlorophyll fluorescence.

The use of CA in refrigerated marine containers continues to benefit from technological and scientific developments. CA transport is used to continue the CA chain for commodities (such as apples, pears, and kiwifruits) that had been stored in CA immediately after harvest. CA transport of bananas permits their harvest at a more advanced stage of maturity, resulting in the attainment of higher yields at the field level. In the case of avocados, CA transport facilitates use of a lower shipping temperature (5 °C) than if shipped in air, since CA ameliorates chilling injury symptoms. CA in C) than if shipped in air, since CA ameliorates chilling injury symptoms.

At the commercial level, CA is most widely applied during the storage and transport of apples and pears. It is also applied to a lesser extent on kiwifruits, avocados, persimmons, pomegranates, nuts and dried fruits. Atmospheric modification during long-distance transport is used for apples, avocados, bananas, blueberries, cherries, figs, kiwi-fruits, mangoes, nectarines, peaches, pears, plums, raspberries and strawberries. Technological developments geared toward providing CA

during transport and storage at reasonable cost (positive benefit/cost ratio) are essential if the application of this technology to fresh fruits and vegetables is to be expanded.

Although MA and CA have both been shown to be effective in extending the post-harvest life of many commodities their commercial application has been limited by the relatively high cost of these technologies. There are however a few cases in which a positive on investment (cost/benefit ratio) can be demonstrated. In a comparison of losses due to decay during retail marketing of strawberries shipped in air and those shipped in an environment consisting of 15 percent CO_2-enriched air (modified atmosphere within pallet cover), the use of modified atmosphere was observed to reduce losses by 50 percent (an average of 20 percent losses was sustained in strawberries shipped in air vs. 10 percent losses in those shipped by MA). The economic loss of 10 percent value (US$50-75 per pallet) was much greater than the cost of using MA (US$15-25 per pallet).

Use of controlled atmosphere (CA) during marine transportation can extend the post-harvest-life of those fruits and vegetables that would normally have a short post-harvest-life potential, thereby allowing the use of marine transportation instead of air transport for the shipment of such produce. In terms of cost and benefit, savings, realized with the use of marine transportation are much greater than is the added cost of CA service.

2. Ethylene Exclusion and Removal

Many green vegetables and most horticultural produce are quite sensitive to ethylene damage. Their exposure to ethylene must therefore be minimised. Ethylene contamination in ripening rooms can be minimized by 1) using ethylene levels of 100 ppm instead of the higher levels often used in commercial ripening operations, 2) venting ripening rooms to the outside on completion of exposure to ethylene, 3) at least once per day ventilating the area around the ripening rooms and installing an ethylene scrubber, and 4) use of battery-powered forklifts instead of engine-driven units in ripening areas.

Ethylene-producing commodities should not be mixed with ethylene-sensitive commodities during storage and transport. Potassium permanganate, an effective oxidizer of ethylene, is commercially used as an ethylene scrubber. Scrubbing units based on the catalytic oxidation of ethylene are used to a limited extent in some commercial storage facilities.

Return on investment in reducing ethylene damage

A University of California study showed that the use of an ethylene scrubber in storage facilities used for lettuce significantly reduced russet spotting. The difference in value of lettuce that was protected from ethylene vs. that which was exposed to ethylene was estimated to be 20 to 25 percent, which was greater than the cost of the ethylene scrubber. Similar results were found with kiwi fruits, which soften very rapidly when exposed to ethylene levels as low as 50 ppb.

Treatments to enhance uniformity in fruit ripening

Ethylene treatment is commercially used to enhance the rate and uniformity of ripening of fruits such as bananas, avocados, mangoes, tomatoes, and kiwifruits. Optimal ripening conditions are as follows:

Temperature	18 °C to 22°C
Relative humidity	90 to 95 per cent
Ethylene Concentration:	10 to 100 ppm
Duration treatment	24 to 74 hours depending on fruit type and stage of maturity
Air circulation	Sufficient to ensure distribution of ethylene within the ripening room
Ventilation	Require adequate air exchange in order to prevent accumulation of O_2 which reduces the effectiveness of C_2H_4

Epilogue

It augers well that there is a better appreciation of effective and efficient post-harvest management (PHM) of food commodities especially of perishable kind as compared to situation in the past when production and productivity alone were the major criteria for achievement. This is especially true for India where the realisation has come only late and researches on PHM got a boost and the Government has also come out with policies and strategies to derive maximum benefit from the commodity by not only adopting Good Production Practices (GPP) but also reducing huge post-harvest losses by harvesting/plucking/picking at optimum maturity, improving the infrastructure for safe handling, transit or long term storage, packaging and transport under cool condition for boosting the shelf life. With the increasing growth of economy, a large middle class has (200-250 million) has emerged in India which has the capacity and willingness to buy quality goods at competitive price. Further, the intake of fruits and vegetables in the diet has also been increasing for meeting the requirement of vitamins, mineral and fibres etc. Also, there is increasing demand of processed (RTC, RTE, RTS) food due to convenience and its year round availability. There is an increasing demand for fresh and processed products amongst India Diaspora and other communities in the West Asia, Europe, etc.

Even though there has been tremendous spurt in the production of fruits and vegetables, the scenario at processing and value addition is not very impressive. Still, the levels of processing are low and most of processing is done in un-organized sector which has least concern / knowledge about quality and safety aspects so crucial for a better acceptance of processed produce at domestic and international level. Obviously, there is a great need for achieving quantum jump in organized. This can happen by developing/ strengthening backward and forward linkages, emphasis on high quality of raw materials, effective PHM including safe handling, transport and storage and

efficient marketing. In this value chain, the importance of producers/growers needs to be highlighted. They need to be sensitized/trained on the GPP, safety and quality and given access to latest technology, effective cold chain and strong market intelligence. ICT will play an increasing role in the PHM for empowering all stakeholders.

The future of fruits and vegetable, both in raw and processed form, is bright and beside providing quality, safe, healthy, nutritive food for huge domestic market in India but also capture a good slice of international market as well. The need is to devise suitable strategies for effecting necessary changes in the current practices which are ripe for such action.

Postharvest Handling of Fruits and Vegetables Horticulture Technical Note

Abstract

Appropriate production practices, careful harvesting, and proper packaging, storage, and transport all contribute to good produce quality. This publication covers postharvest practices suitable for small-scale operations, and points out the importance of production and harvesting techniques for improving quality and storability. Various methods for cooling fresh produce are discussed, and resources are listed for further information, equipment, and supplies.

Introduction

You have spent months working in the fields, and now have a bountiful harvest of beautiful fruis and vegetables. You want to ensure that your customers will also enjoy this healthy harvest. Howe can you best maintain the quality and safety of your produce as it travels from the field to the table ? How can produce be stored so that it does not need to be sold immediately? High-quality, disease-free produce with a good shelf life is a result of sound production practices, proper handling during harvest, and appropriate postharvest handling and storage.

Sanitation

Sanitation is of great concern to produce handlers, not only to protect product against postharvest diseases, but also to protect consumers from food borne illnesses. *Salmonella, Chryptosporidium, Hepatitis, and Cyclospera* are among the disease-causing organisms that have been transferred via fresh fruits and vegetables. Use of a disinfectant in wash water can help to revent both postharvest diseases and food borne illnesses.

The effectiveness of chlorine concentrations are reduced by temperature, light and interaction with soil and organic debris. The wash water should be tested periodically with a monitoring kit,

indicator strips, or a swimming pool-type indicator kit. Concentrations above 200 ppm can injure some vegetables (such as leafy greens and celery) or leave undesirable off-flavours.

Ozonation is another technology that can be used to sanitize produce. A naturally occurring molecule, ozone is a powerful disinfectant. Ozone has long been used to sanitize drinking water, swimming pools, and industrial wastewater. Fruit and vegetable growers have begun using it in dump tanks as well, where it can be thousands of times more effective than chlorine. Ozone not only kills whatever food borne pathogens might be present, it also destroys microbes responsible for spoilage. A basic system consists of an ozone generator, a monitor to gauge and adjust the levels of ozone being produced, and a device to dissolve the ozone gas into the water. Systems cost anywhere from US $10,000 to US $1,00,000 and should be installed by an ozone sanitation company experienced in produce industry applications.

Hydrogen peroxide can also be used as a disinfectant. Concentrations of 0.5% or less are effective for inhibiting development of post harvest decay caused by a number of fungi. Hydrogen peroxide has a low toxicity rating and is generally recognized as having little potential for environmental damage. The ATTRA publication ***sources for Organic Fertilizers and Amendments*** lists several sources of food-grade hydrogen peroxide.

Ethylene

Ethylene, a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it. The old adage that one bad apple spoils the whole bushel is true. Damaged or diseased apples produce high levels of ethylene and stimulate the other apples to ripen too quickly. As the fruits ripen, they become more susceptible to diseases.

Ethylene “producers” should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life, and specific symptoms of injury. Some examples of ethylene effects include:

- Russet spotting of lettuce along the midrib of the leaves;
- Loss of green colour in snap beans;\
- Increased toughness in turnips and asparagus spears;
- Bitterness in carrots and parsnips;
- Yellowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower;
- Accelerated softening of cucumbers and summer squash;
- Softening and development of off-flavour in watermelons;
- Browning and discoloration in brinjal pulp and seed;
- Discoloration and off-flavour in sweet potatoes;
- Sprouting of potatoes;
- Increased ripening and softening of mature green tomatoes; and

- Shattering of raspberries and blackberries

Ethylene producers include apples, apricots, avocados, ripening bananas, cantaloupes, honeydew melons, ripe kiwifruit, nectarines, papayas, passionfruit, peaches, pears, persimmons, plantains, plums, prunes, quinces, and tomatoes.

Mixed Loads

When different commodities are stored or transported together it is important to combine only those produce products that are compatible with respect to their requirements for temperature, relative humidity, atmosphere (oxygen and carbon dioxide), protection from odours, and protection from ethylene.

In regard to cross-transfer of odours, combinations that should be avoided in storage rooms include : apples or pears with celery, cabbage, carrots, potatoes, or onion; celery with onions or carrots and citrus with any of the strongly scented vegetables. Odours from apples and citrus are readily absorbed by meat, eggs, and dairy products. Pears and apples acquire an unpleasant, earthy taste and odor when stored with potatoes. It is recommended that onions, nuts, citrus, and potatoes each be stored separately.

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72-82

Residues Control by Using Rapid Bioassay of Pesticide Residues (RBPR) for Market Inspection and Farm Education

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Abstract

Following the execution of residue control program using housefly bioassay technique during 1964-1987, Taiwan Agricultural Research Institute has renovated and implemented a rapid bioassay method since 1985. The established rapid bioassay of pesticide residues (RBPR) system is aiming at detecting the noxious organ phosphorus, carbamate insecticides as well as ethylene bisdithiocarbamate fungicides using housefly acetylcholinesterase and *Bacillus thuringiensis* as the probes. Standard assay procedures have been developed to detect the residues on fruits, vegetables, rice, tea, spices, etc., and are able to complete 50 shipments within 4-6 hours. In Taiwan, more than 300 RBPR stations inspect a half million agricultural products annually, and have constructed a residue control system that covers farmer association and farm cooperative in production areas; wholesale markets; food suppliers for military services, school and group lunching; supermarket chain stores; private enterprises, etc. RBPR has also been adopted by the Republic of Korea, Vietnam, Philippines, Panama and many Southeast Asian countries, and 11 international RBPR training workshops were held during 1993-2010. The institute also is responsible for supplying RBPR reagent kits and high quality of housefly acetylcholinesterases to local users and abroad.

Keywords: Insecticide, Fungicide, Residue, Acetylcholinesterase, RBPR.

Introduction

Agriculture in Asia is usually different from America or Europe on farm scale and the marketing system. The pesticide residue monitoring system develop by the Environmental Protection Agency (EPA) of the United States usually is not functioned as a safety valve for consumer protection, but is mainly designed to conduct the general survey of residue situation and offer suggestions for long-term improvement. The immediate consumer protection action can not be derived from the EPA residue control practice. “You detect what you haven’t eaten” versus “you detect what you have already eaten“, clearly differentiates the residue preventing mechanism from the residue monitoring mechanism.

Unfortunately, pesticide residues are only monitored by the chemical analysis methods in developed countries such as United States and Japan, which may not be practical for regions such

as Taiwan and Southeast Asia countries. Chemical analysis is precise enough but lack of speed, hence is incapable of screening out the residue contaminated vegetable before been served and mostly only serves as investigation purpose. In Taiwan, the Food and Drug Administration of Department of Health conducts a general survey that analyzes 1,800 fruit and vegetable samples annually (Lee *et al*., 2008; Kuo *et al*., 2009), but is unable to stop the contaminated shipments before marketing, i.e., all vegetables confirmed with pesticide residue violation had been sold and consumed. Detailed residue monitoring is needed, but the government is also responsible for stopping the residue contaminated shipments for further trading, and that is the major purpose of RBPR (Rapid Bioassay of Pesticide Residues) to be involved in residue control.

Starting from the first RBPR station in central Taiwan in 1985 and increased to 38 stations within five years, the RBPR system supervised by Taiwan Agricultural Research Institute (TARI) grows steadily to more than 300 in 2010 and has established a strong residue control network island-wide. Current RBPR technology can deal with the most hazardous pesticides mentioned in the Food Quality Protection Act (FQPA) legislated in 1996 in the United States, i.e., organophosphorus (OP) and carbamate insecticides (Carb) (EPA, 2000 & 2002). In other word, the action we have been taken for the past years fits exactly the true spirit of the FQPA and has gained popularity and acceptance to whatever country it has been introduced.

The technology is simple, the detection speed is quick, the expenditure is low and the result is clear in toxicological sense. RBPR is designed particularly for its residue preventing function, and has been generally accepted in Taiwan, Korea, Vietnam and Panama because this rapid monitoring system profits the general public by stopping the pesticide contaminated shipments in time.

Prospects of Rapid Monitoring and Control of Pesticide Residues

Vegetables are essential parts of the human diet. They provide carbohydrates, proteins, lipids, vitamins and mineral elements. The production of vegetables nowadays depends heavily on new technologies, and pesticide usage is almost unavoidable especially in the subtropical and tropical regions where vegetable production confronts with serious insect and disease problems. Although new safety-concerned pesticides have been developed in the past two decades, many pest problems still remain unsolved and rely heavily on hazardous pesticides, particularly, the neurotoxic OP and Carb insecticides (Cheng *et al*., 1988; Fukuto, 1978; Kao and Cheng, 2001; O'Brien, 1967). Fungicides are generally less toxic to animals, but one major group, ethylene bisdithiocarbamates (EBDC's), has a problem in ethylenethiourea (ETU), an impurity as well as carcinogenic metabolite.

In early 1960's, when synthetic pesticides were only very few, residue monitoring and prevention were simple and easy. Later, the number of chemical pesticides increased tremendously, and monitoring samples for unknown residues has become an enormous task in the laboratory. Not until every pesticide been examined, to ensure that vegetable free from residue is not possible. In

developed countries, large farm scale makes residue control easier, particularly when the cold storage and transportation allow extra time for recall. On the other hand, many developing countries have only small farms and the farmers are mixing and spraying pesticides independently, which makes the residue control an impossible mission. If the pesticide residue prevention still remained as a country's public health policy, an alternative rapid residue screening process based on the toxicological technology can help to stop the agricultural products with signs of contamination.

In reality, pesticide residue monitoring does not have any practical value for consumer protection if the system could not prevent the contaminated vegetables from been consumed. Many residue-related problems can also be corrected simply by installing an economic, rapid, sensitive and accurate screening process before the laborious chemical analysis is applied. Therefore, constant monitoring of fruits and vegetables for these dangerous pesticide residues is feasible, and to carry out the control action is absolutely needed for consumer protection.

Housefly Bioassay in Taiwan (1959-1987)

After the first OP insecticide, parathion, was introduced to Taiwan for agricultural pest control in 1952, more and more residue problems arose and had initiated official pesticide residue survey and research programs since 1959. The housefly (*Musca domestica* L.) bioassay (HB) method was developed by TARI during 1959-1962, and had put into practice during 1964-1987 by 18 bioassay stations in major wholesale markets.

In 1980s, the number of registered synthetic insecticides increased rapidly and the introduction of synthetic pyrethroids (SP) imposed another problem for HB because the HB could not distinguish the much safer SP from the more dangerous Carb and OP insecticides. Questions also came from the consumers as the general public were not satisfied with the pre-harvest warning, and demanded for effective residue control on harvested vegetables. Unfortunately, the duration between the arrival of agricultural products at market to auction was only three and half hours in the wholesale markets, and the 6-hour HB method could not fulfill this request, hence the main task was to speed up the test.

Development of RBPR in TARI (1980-)

In order to develop a rapid residue screening method, TARI had analyzed the *pro* and *con* of several residue analysis methods. The chemical analysis is detailed, sensitive and accurate because advanced analytic instruments such as gas chromatography (GC), high performance liquid chromatography (HPLC) or even GC-MS and LC-MS are used in some cases. One of the common features of those instruments is the sample should be clean and free from undesirable impurities, hence the time-consuming and laborious cleaning process is unavoidable in sample preparation.

When looking for the potential alternatives, we found that the common and unique feature of

pesticides is their toxicities. For instance, insecticides can kill insects; fungicides can block the growth of fungi and microbes (Wagner, 1983), etc. By selecting proper testing organisms or biochemical entities, pesticide toxicities can easily be detected without the fear of interference from water, pigments, wax, carbohydrate, proteins, etc. Specific toxicity test can single out the target pesticide group from the rest of plant materials without the time consuming clean-up, and that is why toxicity tests were select to develop RBPR.

Insecticide residue assay using housefly acetylcholinesterase

In 1982, TARI successfully purified the acetylcholinesterase (AChE) from housefly heads (Chiu *et al*., 1991; Guilbault *et al*., 1970; Lewis, 1967). Within 6 months, lyophilized AChE powder was obtained and ready for the *in vitro* detection of OP and Carb insecticides based on the well-known Ellman's test shown in Fig. 1 (Ellman, 1959).

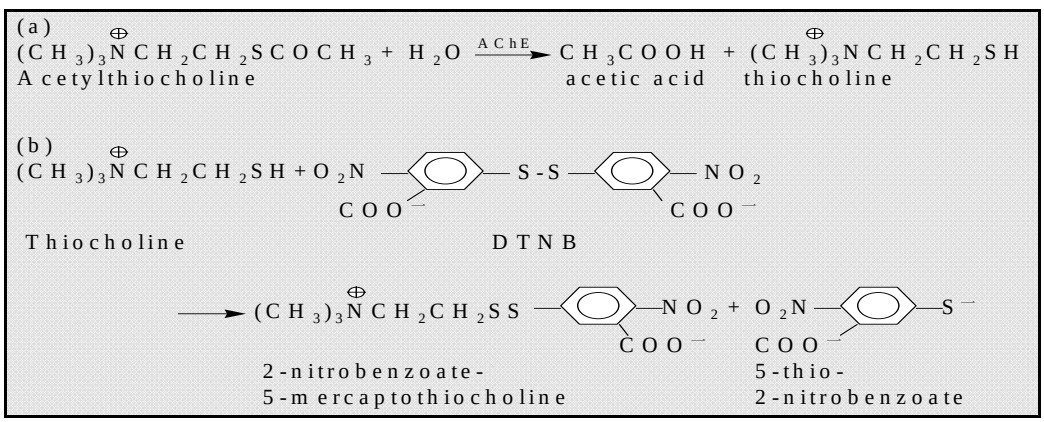

Figure 1. Reaction of AChE with acetylthiocholine and DTNB.

After testing for two years, AChE test was launched in 1985, and the first RBPR station was established in Hsi-lo vegetable wholesale market. Later, AChE test was refined to include organothiophosphates by incorporating bromine water in the extraction procedure, which can convert the organothiophosphates to their corresponding oxo-analogues and increase the detection limit. Modification on sampling procedure, for example, use buffer as extraction solution and increase the incubation time, can greatly improve the detection limit of methamidophos, profenofos, etc. (Cheng *et al*., 2000; Cheng, unpublished data).

There are also disadvantages in toxicity tests. For instance, Carb and OP insecticides act on AChE and make this enzyme an excellent biological probe (Voss, 1966; Voss *et al*., 1971), but the inhibition of enzyme can not distinguish one OP from another OP, OP from Carb, or one Carb from another Carb.

Fortunately, the obstacle was later overcome by combining the bioassay with the simple and rapid thin layer chromatography (TLC) technique. Once the pesticide was identified by the rapid qualitative analysis, the residue concentration could be estimated from the correlation of concentration and toxicity of that particular insecticide. To process large quantities of vegetable samples, the AChE test was modified by using the microplate reader in the enzyme kinetic mode, which has been adopted in major markets since 1993.

Fungicide residue assay using *Bacillus thuringiensis*

The second test of RBPR is specially designed for the EBDC's not only because it once consisted 70% of the fungicide market, but also due to its carcinogenic impurity and metabolite, ETU (Fishbein, 1977). In this regard, a number of microbes including *Bacillus cereus*, *Saccharomyces cerevesiae*, *Ustilago maydis*, and *Bacillus thuringiensis* (Bt) were tested, and Bt was finally chosen for its safety, sensitivity, availability and reliability (Chiu *et al*., 1991; Hammerschla and Sisler, 1973; Salama *et al*., 1981). By incorporating the triphenyl tetrazolium chloride (TTC) as described by Bitton and Dutka (1986) to detect the dehydrogenase generated during Bt replication (Fig. 2), this assay method has been proven to be practical, economical, rapid and even more sensitive than the CS_2 test. In addition to the EBDC's, Bt test is also very sensitive for the detection of antibiotics, chlorothalonil, TPTA, etc. Bt test has been incorporated into RBPR system in 1989 and can detect hundred of samples within hours. By adopting Bt test, not only the analysis time is shortened, tremendous saving in manpower and resources in fungicide analysis can also be achieved.

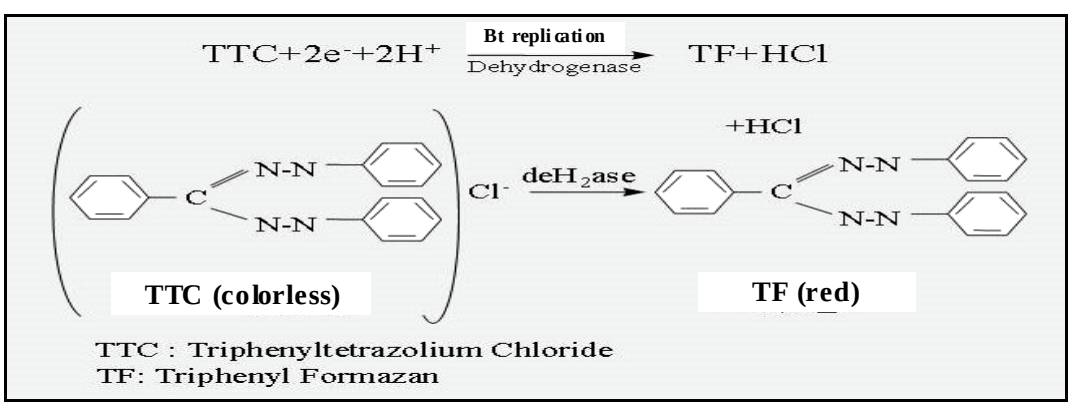

Figure 2. Using TTC to detect the dehydrogenase generated by the growth of Bt.

Features of RBPR

In Taiwan, the Food Safety Law defines the standard procedure for pesticide residue analysis, which is the same for either fresh vegetables or storable products. For rice, the residue analysis may be in time for the residue clearance because rice can be stored for a period of time. As to the

fast marketing fruits and vegetables, the same safety regulation became incompetent because when the lengthy residue analysis was completed, the contaminated vegetable had already been sold and consumed.

Many efforts have been made to correlate the sensitivity of RBPR to that of chemical analysis. These efforts are worthwhile but not essential since the practicability of RBPR depends on the actual situation of pesticide usage in that region. If Carb, OP and EBDC's are used, it is suitable to apply RBPR; but when SP, insect growth regulators and other category of insecticides are used, RBPR is less fit (Fukuto, 1978). In other words, the practicability of RBPR is dynamic or pesticide-dependent.

Detect the cumulative toxicity

The tolerance of pesticide is estimated at the chronic toxicity, and usually at sub-ppm level; however, high levels of residues are more hazardous than the sub-ppm problem. RBPR can detect the total toxicity of different pesticides within specific group i.e., the higher residue, the easier to detect, hence can screen out the major residual problem. For a pesticide, if RBPR is sensitive enough to reach its chronic tolerance, it is perfect; but when RBPR is not sensitive enough to reach the tolerance, it still can prevent the dangerous acute or sub-acute poisoning. Particularly when the farmers tend to use many pesticides in the tank mixture, chances to violate the regulation is higher.

Efficient residue control

Since RBPR is able to detect the residues of OP and Carb in 10 minutes, if the sample sent to the station was for pre-harvest check, delay the harvest also can be attained. But when agricultural products are harvested and delivered to market or food processing center, the rapid screening process will act as safety valve, and products with higher risk can be withheld for further trading or processing in time.

Simply follow the standard assay procedures, two technicians can detect insecticide and fungicide residues of 50 samples within 4-6 hours and screen out high residue risk shipments. For massive samples assay in the wholesale markets, major suppliers or supermarket chains, incorporate the microplate reader can shorten the assay time and expand the control efficiency.

Cost saving

Chemical analysis is originally designed for individual pesticide detection. The residue analysts gathered different protocols, summarized them, abstracted the common features, reorganized the procedures with compromise, and adjustments were made to conduct multiple residue analysis. Until now, none of any multiple analytical methods can cover all pesticides. For any unknown samples, several methods, instruments as well as clean-up procedures are needed to

complete the analysis. In Taiwan, analysis of the residues of 200 pesticides in one sample costs 150 to 300 US dollars, and average 3-7 days is needed. Without a screening process, all those efforts might just prove to be a 90% waste in the end.

RBPR can reduce both the labor and cost of analytical materials; meanwhile minimize the polluted organic wastes in the chemical analysis. TARI produces the housefly AChE and supplies RBPR reagents to local users and abroad, and the reagent cost of one assay is 0.5 US dollar. When conduct massive samples using the microplate reader, the cost is even lower because more diluted reagent is used.

Management of RBPR

Ever since the establishment of the first RBPR station in 1985, the number of stations increases gradually and the testing items also are expanded from fruit and vegetable to tea, rice, spices, etc. Currently, more than 300 stations have been established in Taiwan, and users include farmer associations and farm cooperatives in crop production areas; wholesale and retailed markets; military food supply system; school and group lunching programs; supermarket chains and private companies; public health system and education purpose.

In practice, three fronts of RBPR are involved in the residue control in Taiwan. The first front is the ready-to-harvest stage in producing areas that facing the growers directly; most of the stations are established by local farmer association or farm cooperative. The second front is the delivery stage; wholesale markets in production districts or major cities are responsible for the safety check. The third front is closer to the consumers; suppliers for military food, group meal and school lunching as well as supermarket chain stores are the final check points. Every year, more than half million of agricultural products are screened by RPBR, and nearly 10,000 shipments are rejected due to toxicity risk. Effective actions taken by the RBPR stations include delay harvest, thorough wash and recheck, warning but accept the shipment, reject the shipment, destroy the products, etc.

Several factors contributes to the success of RBPR include feasible technology, sound training and audit programs, high quality reagents, efficient feedback mechanism, widely acceptance by the users and consumers, etc.

Intensive training program and audit system

In Taiwan, all the technicians work for RBPR need to be trained by TARI in a two-day training sessions. Lectures and practicum on basic principles, application status, and technical details on sampling, extraction, assay procedures, reagent preparation, instrument setting, etc. will be given. A certificate validates for two years will be issued after the station hand in the monthly report steadily. Renewal of certificate will be made for the technicians and stations that passed the

annual evaluation; any station did not send in the report for 6 months will be rejected from the RBPR system.

Production of high quality housefly AChE

The core of TARI's residue control program is the susceptible housefly colony established at TARI since 1958. Mass rearing of this housefly colony has been ongoing for more than half century and produces 200,000 flies weekly. After sophisticated purification processes, high quality AChE can be obtained from housefly brain and provided needed enzyme material for RPBR application. Compared to the commercial AChE products of electric eel, horse, etc., TARI's AChE is extraordinarily stable and highly sensitive to the neurotoxic agent, and has gained great popularity by local biotechnology companies and users from abroad.

Efficient feedback system

Residue problems may arise occasionally due to improper pesticide application, disobey pesticide labeling, etc. Based on the working reports provided by the RBPR stations, TARI gathers the latest information on residue situation island-wide and releases RBPR Newsletter every month. Whenever there is unusual signs or risk of residue in particular area or crop, a case study will be initiated through massive sampling from the markets or production areas; qualitative and quantitative analysis of residual pesticides will be conducted; suggestion or warning will be made to related parties to ensure the safety of agricultural products. Many stations are actively involved in such kind of study and have provided useful information regarding production status.

Modification of assay techniques

When more and more RBPR stations are established, we need to handle various agricultural products other than fruits and vegetables, especially when containing some natural inhibitors. For example, modification of sampling and assay procedures have been made for rice, tea, citrus, strawberry, potato, onion, ginger, garlic, corn, and some spices, Chinese medicines, various mushrooms, etc., and put into practice by needed stations (Cheng, *et al*., 2000; Kao *et al*., 2003).

RBPR stations in major wholesale markets and supermarket chain stores usually inspect more than one hundred shipments per day, and have installed microplate reader to speed up the testing processes; while the stations in regional production area use spectrophotometer to examine 10-50 samples daily. For the tea and rice production areas, the use the microplate reader is also recommended because massive samples may come in within very short period. Standard testing procedures of microplate reader and spectrophotometer are available and incorporated into training upon request.

RBPR International

Sponsored by the Food and Fertilizer Technology Center (FFTC) and Council of Agriculture, 11 RBPR training workshops have been held since 1994 in Taiwan, Philippines, Thailand, Republic of Korea, Vietnam, etc. (FFTC, 1994 & 2009). Asian Vegetable Research and Development Center also sent the trainees from Vietnam, Lao and Cambodia to TARI to learn for RBPR techniques.

A similar program in Korea was initiated by Dr. Chan-Hoi Choi, who introduced RBPR to the National Agricultural Cooperative Federation (NACF) in 1996. After continuously testing, NACF sponsored more than 200 local farmer associates to establish RBPR stations within two years and are responsible for the follow-up training programs. The largest wholesale market in Seoul, Garak Wholesale Market, implements RBPR technology since 1998 and has combined RBPR with chemical analysis to execute a residue control program that is efficient enough to protect the consumers. Korea Food and Drug Administration has been using RBPR as rapid screening tool since 1998. Hyundai and Shinsegae Department Stores, Samsung Everland and other supermarket chains also apply RBPR to safeguard the quality of fruits and vegetables they supply.

Another example is in Vietnam. The Sub-Institute of Agriculture Engineering and Post-Harvest Technology in the Ho Chi Min City has adopted RBPR in 1997 and conducted residues survey programs since then. By applying RBPR technology, Mr. Tran Van An and his colleagues won the National Safety Prize in 2003 for their dedication in solving pesticide residue problems.

After the lectures on RBPR technology given by Dr. Edward Y. Cheng in mainland China in 1998, similar rapid bioassay method has been developed by several institutions. The national standard method was announced in August 2003 by the Department of Agriculture of People of Republic China, and has established a detection network.

In 2004, Mr. Miguel Zheng of the Taiwan Mission of ICDF (International Cooperation and Development Fund) presented the RBPR technology to the government of Panama, and started to conduct a three-year cooperative project between Panama and Taiwan government. The counterparts of this project include Ministry of Agriculture, Ministry of Health, Panama Municipal and Panama Agricultural Research Institute and have established national residues monitoring system and 3 bioassay laboratories including one pilot laboratory in Central Agricultural Market in Panama City. The pilot laboratory executes the annual investigation to evaluate the level of pesticide contamination and illustrate the high risk production areas. Collaboration with dealers and producers as well as communication with the consumers has been ongoing. RBPR technology is well accepted by major dealers in central market and supermarket chain stores such as RS, REY, SUPER 99, Machetazo, etc. In October 2008, a WTO committee praised the Taiwan ICDF for the RBPR work in Panama that targeting specific areas to be improved on a relatively small budget.

All of these indicate that people appreciate the real action rather than the annual report on residue survey. Due to the availability and easiness, RBPR can immediately stop the residue to poison people, and is a no boundary program that can be used in any region. The cost to implement RBPR is low, while the achievement has already been proven to be significant. The general public appreciates RBPR technology even though it is unable to detect all the pesticides. The consumer parties showed their understanding and patience as more research is needed for some pesticides that still can not be detected by current method. It has formed a unique working network on pesticide residue prevention.

We believe that through the application of this technology, pesticide residue working groups will win the heart of the consumer who usually supervises the residue control agencies of government closely. We would like to share these concepts and experiences with the people who have been troubled by the residual problems. In the future, we may work together to ensure safer agricultural products and better tomorrow.

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Country Papers

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Technology on Reducing Post-harvest Losses and Maintaining Quality of Fruits and Vegetables in Bangladesh

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Abstract

The post-harvest handlings of fruits and vegetables scenario is quiet unsatisfactory and mostly comprise of traditional techniques practiced by the growers, traders and processors, owing to which considerable deterioration in physical and nutritional qualities of the harvested produced in Bangladesh. It is estimated that the post-harvest loss of fruits and vegetables in the country is about 25-35% (Mia and et-al, 2008). Therefore, improvement of these indigenous practices and development of low cost new technologies through precise research efforts has now become essential to prevent the huge post-harvest losses of fruits and vegetables in view of ever increasing, demand for food and nutrition. In the development plans, considered post-production phenomenon merely as a support programme and the allocated resources for this sub-sector was only negligible amount of the total investment in agriculture sector. Under such situation, reduction of post-harvest losses has become the prime issue to increase the availability of fruits and vegetables at household level. However, the existing status of post-harvest handles including packaging, transportation, storage, processing and preservation of our harvested fruits and vegetables and to identify the loss reduction interventions. The experience in developed countries shows that the post-harvest losses of fruits and vegetables produce could be reduced by using the technology together with appropriate selection, preservation, transportation, packaging, processing and marketing. However, the developing country like Bangladesh suffer much of the post-harvest losses due to a number of factors such as lack of adequate knowledge and information, the unavailability of appropriate technology under funded research and development. However, many countries in this region possess their own indigenous, inherited knowledge in the field of post-harvest technology which perhaps has been neglected in the hurry to modernize. It is high time that the scientists and policy makers come together, discuss the issue of post-harvest technology and developed knowledge to facilitate the exchange of available technology and information between them.

Introduction

Agriculture is the predominant sector of the economy of Bangladesh. The agriculture sector creates not only large number of employment opportunities but it also provides a source of livelihood to the majority of the people of Bangladesh. The classical domain of investment on agriculture sector has undermined the role of post-harvest technology. Most of the fruits and vegetables are good sources of vitamins and minerals. So, emphasis should be given on availability and of consumption of various quality fruits and vegetables. The low consumption of fresh fruits and vegetables during off-season should be considered as a major concern from the standpoint of nutritional status of a country.

In Bangladesh, the production of vegetables is 2.7 million ton, potato 6.6 million ton and fruit is about 5.5 million ton (BBS, 2008). The present productions can hardly fulfill 50% requirements of the nation. Besides a significant portion of fruits and vegetables (25-35%) is lost due to improper post-harvest handling and processing resulting huge shortage of fruit and vegetable in the country. That is, consumption of the fruit and vegetable is almost half than the recommended doses. Consequently, vast majority of the peoples are suffering from various nutritional deficiency diseases.

Different Operations of Fruits and Vegetables after Harvesting

Harvesting of fruits and vegetables, are done manually. During harvesting maturity indices are not yet followed by farmers. To catch the high prices, farmers are generally harvest their fruits and vegetables very early when the nutritional quality is poor. Proper grading, sorting, packaging even pre-cooling is not generally done. Resulting, deterioration has been starting just after harvesting. However, the losses at the different stages of storage, grading, sorting, packaging, transport and finally marketing as a fresh produce is account for 25-35 percent. Such an enormous loss has proved a great handicap in exploiting the full potential of the increasing production of these crops and thereby improves the rural income, employment and nutrition of the population. The production and marketing of these commodities suffer from the uncertainty and instability of the market conditions and since these are grown by small and marginal farmers and handled at the retail level by poor sections, the effect is very frustrating. The infra-structural support available for the handling of about 15 million tonnes of fruits and vegetable, including potato produced annually, is too inadequate in the country. The practices currently in use in post-harvest handling and standards of material or facilities being used for storage, packing and transport are indigenous and outdated, contributing directly to the above loss.

1. Fruits

Maturity indices for mango cultivars namely *Gopalbhog*, *Khirshapat*, *Langra*, *Fazli*, *Bombai* and *Aswina* have been standardized. The optimum maturity time for harvesting;

- *Gopalbogh*, *Khirshapat*, *Langra*, *Fazli*, *Bombai* and *Aswina* were 87-91, 87-95, 97-105,112-120, 97-105 and 139-146 days respectively. The indicators applied were color, specific gravity and sinking and floating behavior of mangoes in salt solutions of different concentration. The mangoes harvested at above age were found to have 9-10 days shelf life at ambient temperature with good eating quality. All the methods are easily adoptable by the growers.
- Mangoes treated with hot water and transported through paper carton or plastic creates performed better in reducing transport losses.
- An evaporative cooler without use of refrigeration was designed and fabrication for short-term preservation of fruits and vegetables during dry season for use at farmer's level with maintaining relative humidity 90-99% and lowering temperature to an extent of 13℃ was attained. This cooler has excellent potentiality for village level storage of harvested fruits and vegetables for a short period.
- Physical injury of banana was minimum when transported in plastic crates.
- For local marketing, litchi having bunches in perforated polyethylene bags which were put in plastic crates for transporting to distant place can be maintained the shelf life for 3 to 4 days.

2. Vegetables

Leafy vegetables viz. spinach, red amaranth and Indian spinach packed in perforated packages give longer shelf life.

Processing and Preservation Technologies of Fruits and Vegetables

1. Preservation of Fruits by Steeping

Preservation by steeping in brine solution has been in practice from time immemorial. Sodium chloride acts as a preserving; conditioning, flavour enhancing and taste-improving agent in the processed and preserved foods. The vegetables preserved by steeping can be used for pickling or home cooking after leaching out the salt and acid. The fruits like green mango, olive, golden apple, *satkora* etc and vegetables like tomatoes, carrot, cauliflower , cabbage, bitter gourd, peas, mushroom and animal foods (meat, fish and poultry) could be preserved in an acidified sulphited brine solution (Ranote et al. , 1991; Pruthi et al., 1990)

Preservation of green mango by steeping

Fresh, sound green mangoes are selected, washed and removed the stalk and cut into slices by hand cutter. After removing the seed and foreign particle again they are washed with clean water, blanched for 2 min at 90^0c and cooled immediately. The blanched slices were soaked in the

solution containing 8% salt. 0.6% acetic acid. 0.02% turmeric powder and 1000 ppm SO_2 in a clean plastic drum and closed airtight and stored in dry, clean and cool place at room temperature. The self-life of the mango slices in the brine solution is 8 months. PRAN group also steeps the mango slices using the same procedure.

Preservation of olive by steeping

Fresh, mature sound green olives are selected, removed the stalk and foreign particles, washed with clean water and blanched for 3 min at 90℃ and cooled immediately. The blanched olives are soaked in the solution containing 8% salt, 0.6% acetic acid, 0.02% turmeric powder and 1000 ppm SO_2 in a clean plastic drum and closed airtight and stored in dry, clean and cool place at room temperature. The self-life of the olives in the brine solution is 8 months.

Preservation of golden apple by steeping

Fresh, mature, sound, green golden apple are selected, removing the stalk and foreign particle washed with clean water and blanched for 3 min at 90℃ and cooled immediately. The blanched golden apple are soaked in the solution containing 8% salt, 0.6% acetic acid, 0.02% turmeric powder and 1000 ppm SO_2 in a clean plastic drum and closed airtight and stored in dry, clean and cool place at room temperature. The self-life of the golden apples in the brine solution is 8 months.

2. Preservation of Fruitpulp

Preservation of mango pulp at ambient temperature

Mango is an important fruit crop in the country with a production of about 0.77 million ton (BBS, 2007). The approximate harvesting period of mango is June-August. Like most other fruit crops, mango is a highly seasonal crop. Mangoes are highly perishable in fresh form and shelf life is extremely limited to about a week only. Preservation of pulp extracted from fresh mangoes in production season can be an alternative way to make it available during the off-season. The semi-processed pulp may be used for processing into products like jam, drinks, squash, nectar etc. This type of processing may be adopted at home level and at community level. The technology is inexpensive and do not need sophisticated equipment and machinery. The small entrepreneur may come forward to adopt the technology especially in the production areas since the technologies are inexpensive and do not need sophisticated equipment and machineries.

Preservation by semi-processing consists of alternation of the biological activity in mango pulp. This is achieved through inactivation of the enzymes responsible for larger number of biochemical reactions that characterize fresh mangoes. In addition to enzyme inactivation, processing eliminates many microorganisms on or within the commodity that might cause rotting or decay so as to prolong the storage life of the product much longer than storage in fresh form.

Mango pulp after extraction should be strained in mosquito net/bamboo made sieves to remove the fibers and other coarse fractions. Heating of pulp should be done to attain temperature of 85-90℃ with addition of 100 ml water per kg pulp followed by 10 minutes heating at this temperature and maintained the acidity at 0.9% with the addition of citric acid. Sodium benzoate (1000 ppm) or KMS (1000 ppm) should be added to the pulp before 2 minutes of completion of heating. After completion of heating, the pulp filled hot into sterilized bottles followed by further processing of the filled bottles for 20 minutes in boiling water. The processed bottles are scaled and kept inverted for 5 minutes. When cool, the mouth of the filled bottles is dipped in molten wax and then the bottles are stored in a dry, clean and cool place. The size of the bottles may vary but the steps of sterilization, hot filling, inverting, waxing, cooling etc. should be rigidly followed for any size of bottle, PRAN group also preserves these pulps by mechanized process and follows the HACCP requirements.

Preservation of tomato pulp at ambient temperature

Tomato is one of the most important vegetables in our country. It is extremely perishable and can not be preserved in fresh stage. Huge post harvest losses of the harvested tomatoes may occur due to inadequacies in transportation and storage facilities which brings substantial loss to the growers and hence to the national economy. Preservation of tomatoes as semi-processing system not only takes care of the marketable surplus but also ensures the supply of raw materials for finished products like sauce, ketchup, drink etc, (Rodrigez et al., 1975; Nickerson and Ronsivalli, 1976). A simple technology of concentrating tomato pulp kept in locally available containers might be a solution to the problem of huge tomato loss during harvesting period.

Tomato pulp after extraction and strained through mosquito net/bamboo made sieves to remove the seeds and other coarse fractions. The pulp is concentrated in open cooker as per method outlined by Bhatia (1982). The pulp is concentrated to 10^0B from the initial TSS 4^0B and then citric acid0.2% and sodium benzoate (1000 ppm) are added. The pulp is filled hot into sterilized bottles followed by further processing of the filled bottles for 20 minutes in boiling water. The processed bottles were sealed, kept inverted for 5 minutes. When cool, the mouth of the filled bottles is dipped in molten wax and then stored in a dry, clean and cool place. PRAN group also preserve these pulps by mechanized process and follows the HACCP requirements.

3. Preservation of Fruit Slices in Sugar Syrups

Select firm-rip fruits (mango, pineapple, jackfruit etc.) and wash, peel and slice. Sterilize clean neutral glass containers by dipping them in boiling water for at least half an hour. Place the fruit slices in the container and then put 30-40^0B (30-40% sugar in water w/w basis with 0.05% citric acid) sugar syrup into the filled container up to the brim. Exhaust the bottle in boiling water for 7 minutes. Seal the bottle loosely and process in boiling water for half an hour. Remove the container and place it inverts position. After cooling store it preserves at room temperature.

Transportation of Fruits and Vegetables

In the rural areas, from field to hat/bazaar, the farmers are generally used shoulder slings for transportation of fruits and vegetables. However, for short distance vans (manual) and auto pickup are used. For long distance, fruits and vegetables are transported through truck. Besides roads, fruits and vegetables are also transported by boat or launch. It is very unfortunate that there is no cool chain system in transporting fruits and vegetables. Moreover, the produces are loaded in ways which promotes major problems such as inadequate transport containers, inappropriate staking, inadequate packages, very rough loading method, poor and non existence of air circulation, heating and mechanical injury to the produce. Consequence, a significant portion of fruits and vegetables is lost/ damaged during transportation.

Packing of Fruits and Vegetables

The major portion of the fruits and vegetables are sent directly to the major markets for disposal. The rest of the produced is packed loosely in bamboo baskets, gunny bags, wooden boxes. But banana and pineapple are directly transported by Truck. These consignments are exposed to the sunlight and other weather abbreviations, causing huge losses in their quality as well as total weight. However, mango fruits are packed with bamboo basket with rice straw for internal markets. Report quotes the following factors responsible for the damages of fruits after harvest:

i. Packing either too tightly or too loosely;
ii. Packing fruits of different maturity;
iii. Poor quality packing material and packing cases;
iv. Expose to sun and rain;
v. Delay in disposed, and
vi. Frequent transshipment, loading and unloading and all involving rough handlings.

The shortage of fruit boxes and its high cost has posed another problem for the marketing and distant shipment of fruits. Packing and packaging systems are important of the post-harvest chain of fruits and vegetables. Packages are made of different sizes, shopes and materials depending on the type of the fruits and vegetables and their uses. Generally low cost packages materials are used for transporting or marketing of fruits and vegetables. The materials are used as followed:

i. Bamboo baskets,
ii. Gunney bags and socks,
iii. Plastic creates,
iv. Hardboard, etc.

Standardization of package is not yet established in Bangladesh. However, it varies from 10 kg to 80 kg depending on type of fruits and vegetables as well as distance. For carrying wholesale market the trader’s prepared big bag and its size up to 500 kg capacity.

Processing Fruits and Vegetables into Pickles

Mango, jackfruit, aonla, brinjal, ber (jujube), taikar, Indian olive, and golden apple are under utilised but popular fruits and vegetables were processed into pickles with the ingredients of chilli powder, garlic, ginger, turmeric powder, mustard powder, green chilli, sugar, fenugreek powder, salt, cumin powder, mustard oil and acetic acid.

1. Olive Pickle

Ingredients

Item	Quantity	Item	Quantity
Olive	1 kg	Mustard powder	20 gm
Sugar	100 gm	Cumin powder	2.5 gm
Garlic	30 gm	Fenugreek powder	5 gm
Ginger	60 gm	Salt	50 gm
Chili powder	20 gm	Mustard oil	400 ml
Turmeric powder	10 gm	Acetic acid	15 ml

Methods of preparation

Select sound, tender and mature green olive, wash and cut the slices of the fruits. Blanch the slices for 10 minutes with 0.05% turmeric powder and then drain out the water. Fry the slices in mustard oil and then remove from the pan. Prepare ginger and garlic paste with addition of 1% acetic acid; add chili powder and turmeric powder with paste. Fry the mixture paste in left over mustard oil of the pan. Add fried olive slices, sugar, cumin power, fenugreek powder and mustard powder gradually. At last, add salt and acetic acid and cook up to complete removal of water. Fill the pickles in sterilized glass container keeping the oil layer on the top. Seal the cap airtight and store them at ambient temperature.

2. Mango Pickle

Ingredients

Item	Quantity	Item	Quantity
Green mango	1 kg	Turmeric powder	10 gm
Ginger	60 gm	Salt	50 gm
Garlic	30 gm	Fenugreek	5 gm
Sugar	100 gm	Cumin	5 gm
Chili powder	30 gm	Mustard oil	400 ml
Mustard powder	20 gm	Acetic acid	15 ml.

Methods of preparation

Select sounds, tender and immature green mango, wash and cut longitudinally in to 4 pieces and remove seeds of the fruits. Soak the pieces into 2% salt solution with 0.05% turmeric powder. After removal from the salt solution, blanch the pieces for 5 minutes at 100^0C and drain out the water. Fry the pieces in mustard oil and remove from the pan. Ginger and garlic are made into paste with addition of 1% acetic acid; add chili powder and turmeric powder with paste. Slightly fry the mixture paste in the left over oil of the pan. Add fried mango pieces, sugar, cumin powder fenugreek powder, and mustard powder gradually. At last add salt and acetic acid and cook up to complete removal of water. Fill the pickles in sterilized glass container and sealed airtight and store them in dry, clean and cool place at ambient temperature.

3. Brinjal Pickle

Ingredients

Item	Quantity	Item	Quantity
Brinjal	1 kg	Green chili	30 gm
Dry chili powder	30 gm	Fenugreek powder	5 gm
Garlic	30 gm	Cumin powder	2.5 gm
Ginger	60 gm	Salt	50 gm
Sugar	200 gm	Mustard oil	400 ml
Turmeric powder	10 gm	Acetic acid	15 ml
Mustard powder	20 gm		

Methods of preparation

Select sound long type brinjal, wash and cut into 5 cm pieces and halves them longitudinally. Fry the pieces in mustard oil and then remove from the pan. Green chillies are soaked in 4% acetic acid. Ginger and garlic are made into paste with addition of 1% acetic acid. Add chilli powder and turmeric powder with the past. Fry the mixture paste in the left over mustard oil. Add fried brinjal, green chilli, sugar, cumin powder, fenugreek powder and mustard powder gradually. At last add salt and acetic acid and cook up to complete removal of water. Fill the pickles in sterilized glass container and sealed airtight and store them in dry, clean and cool place at ambient temperature.

4. Garlic Pickle

Ingredients

Item	Quantity	Item	Quantity
Garlic bulb	1 kg.	Mustard powder	10 gm
Sound bulb	30 gm	Cumin powder	5 gm
Ginger	60 gm	Fenugreek powder	5 gm
Sugar	100 gm	Salt	50 gm
Dry chilli powder	30 gm	Mustard oil	400 ml
Turmeric powder	10 gm	Acetic acid	15 ml

Methods of preparation

Select sound garlic, peels the thin skin and wash with clean water. Fry the garlic in mustard oil and the remove from the pan. Ginger and garlic are made into paste with addition of 1% acetic acid and the mix chilli powder and turmeric powder with the paste. Fry the mixture paste in the left over mustard oil. Then add fried garlic, sugar, salt, cumin powder, fenugreek powder and mustard powder gradually to the mixture paste. At last add salt and acetic acid and cook up to complete removal of water. The pickles are then filled in sterilized glass container and sealed airtight and store them in dry, clean and cool place at ambient temperature.

5. Ber and Tamarind Mixed Chutney

Ingredients

Item	Quantity	Item	Quantity
Dry and clean ber	1 kg	Black pepper powder	1 gm
Tamarind	250 gm	Cloves powder	0.5 gm
Sugar	1.25 kg	Cinnamon powder	1 gm
Salt	32 gm	Joyfal	1 gm
Salt (Bit laban)	5 gm	Joyatri	0.5 gm
Dry chilli powder	6 gm	Salt	59 gm
Fenugreek powder	5 gm	Mustard oil	100 ml
Mustard powder	12 gm	Acetic acid	6 ml
Cumin powder	2.5 gm	Sodium Benzoate	0.75 gm
Kawlanji	8 gm		

Methods of preparation

Select ripe and dry ber, wash and then immersed in water for whole nigh. On the following day boil the ber until becomes soft. Remove the pan from the burner and after cooling separate the pulp by pressing with hand. Soak required amount of tamarind pulp in water and the remove the pulp and filter by using a bamboo sieve. Mix the ber pulp with the tamarind pulp and add required amount of sugar and the heat the mixture. Add oil, salt and spices one by one and continue the heating. When the mixture becomes concentrated and acetic acid and cook until the Brix rises to 62^0 B and the add sodium benzoate. Remove the pan from the burner and transferred the chutney into sterile glass jar.

Conclusion

Reduction of post-harvest losses has become the prime issue to increase the availability of fruits and vegetables. A significant portion of the produce is lost but it can be overcome by processing into different products. The processing methods are simple. If practical training and demonstration are provided to the rural people and if they adopt the technology, it will play a vital role in reducing the post-harvest losses of fruits and vegetables. The policy should encourage the gender groups for improving adoption of technology and reducing losses. It can also create job opportunities for disadvantages section of population.

Recommendation and Suggestion

Bangladesh has excellent environmental resources for the production of fruits and vegetables. To meet the challenges on global safety requirements Bangladesh should gradually takes necessary measures throughout the food chain from farm to table for the maintaining international quality and safety of fruits and vegetables. For this, the following recommendation and suggestion may be followed:

- Human resource development (HRD) on post-harvest technologies;
- Infrastructure development for R&D, education, extension, training, input supply, marketing, processing, storage, etc.;
- Development of supply chain for horticultural produces;
- Cooperative basis marketing should be explore;
- To make available like equipments, chemical, glassware for small scale cottage industry;
- The fiscal policy of the government should be conducive for post-harvest development;
- Interest free bank loan should be provided to post-harvest and processed sectors for sustain development;
- Priority should be given towards development and expansion of processing technologies and facilities suitable for export of processed food products;
- Exsumption/ withdraw excise duty, VAT and other taxes, etc. may encourage processed fruits and vegetables; and
- Develop industries for diversified use of agricultural products.

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Vegetable Marketing Channels, Post-harvest and Adjustment in Taiwan

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Abstract

The vegetable production in Taiwan has been unstable in rainy spring, summer and winter seasons. To maintain the balance between production and consumption demand, planned production based on the amounts of domestic production/consumption and imports trade is important, especially when the production and price is fluctuated. Those sensitive for production and marketing vegetables include garlic, onion, cabbage, Chinese cabbage, and Welsh onion. Most vegetables especially leafy vegetables are highly perishable. Cold chain system for vegetable storage is an advanced operation compared to other traditional operations in postharvest handling and marketing channels, which can reduce postharvest loss and maintain quality. To establish a high efficiency agricultural marketing system of vegetables, cold chain system is necessary for sustainable practices.

Introduction

Taiwan is located in the subtropical zone. It has high temperature and heavy rainfall in summer, but warm and dry in winter, with about 822,364 hectares cultivated land for crops production. The output of agricultural and food produces valued at 179.1 billion NT dollars which accounted for 43% of the total agricultural production value in Taiwan in 2008. Among the output of agricultural produce value, fruit crops contributed 38% of the total value, followed by vegetables (27%), rice (17%), flower crops (7%), special crops (5%), upland crops (4%), and other crops (2%).

In Taiwan, the average temperature is over 22℃, so that the temperature keeps high for more than half year. However, climate influences the vegetable production extremely. The rainfalls concentrate in summer, and plum rain, cloudburst, typhoon also happen frequently. With such a condition, it induces serious natural diseases problems for growing vegetables from May to October, so called “summer vegetable problem”. For this reason, the vegetable production is not enough for consumption. In contrast, vegetable grows fast in the winter season after paddy rice. During this period, vegetable is always over-supplied and the price decreases even lower than the production cost.

Vegetable Industry in Taiwan

More than 100 vegetable crops are cultivated on 153,964 hectares of land in Taiwan. The total production exceeded 2.64 million tons valued at 48.5 billion NT dollars in 2008. Table 1 indicated that the cash vegetable was about 65% of production area and 73% of total vegetable production, which mostly are short-time cultural crops, such as leafy vegetables and flowers. Those are high value per unit area and make most income for farmer. The major production area locates in central part of Taiwan, particularly like Yunlin and Changhua County. Yearlong vegetable, including bamboo shoot, taro and yam, etc., was mostly produced in south Taiwan which is about 19% of production area and 12% of production volume. Melons include watermelon, cantaloupe, and strawberry.

In Table 2, the data indicated that vegetable production was an important industry in Taiwan. The vegetable crops to total crops increased form 21.74% in 1992 to 27.09% in 2008. According to the statistics, the vegetable consumption increased from 40 kg per year in 1950 to 120 kg in 2000.

Table 1. The vegetable production in Taiwan from 1995-2008.

Year	Total		Cash vegetables		Yearlong vegetables		Melons	
	Planted area (ha)	Production (M.T.)	Planted area (ha)	Production (M.T.)	Planted area (ha)	Production (M.T.)	Planted area (ha)	Production (M.T.)
1995	174,749	2,887,017	111,222	2,011,715	33,820	410,348	29,707	464,954
1996	178,521	3,098,097	113,024	2,229,869	33,973	361,651	31,524	506,577
1997	182,393	3,056,290	115,628	2,188,904	33,588	394,921	33,177	472,465
1998	180,072	2,911,734	113,987	2,064,417	33,998	385,311	32,087	462,006
1999	183,600	3,513,788	118,439	2,563,797	34,477	411,550	30,684	543,476
2000	177,074	3,262,194	115,569	2,279,210	33,374	388,094	28,131	494,890
2001	173,672	3,045,605	113,637	2,222,768	32,907	365,845	27,128	456,993
2002	179,473	3,461,803	116,945	2,485,830	33,093	386,942	29,435	589,031
2003	165,822	3,093,970	108,954	2,233,743	32,718	392,212	24,150	468,015
2004	168,338	3,064,607	110,715	2,264,830	31,612	356,630	23,011	443,097
2005	160,337	2,654,613	108,903	2,072,316	31,462	270,480	19,972	311,817
2006	157,184	2,877,991	106,017	2,162,465	30,699	357,977	20,468	357,549
2007	154,112	2,595,162	101,776	1,959,713	30,567	326,397	21,769	309,052
2008	153,964	2,640,700	104,979	2,070,571	29,854	288,267	19,131	281,862
Average %	100%	100%	65%	73%	19%	12%	16%	15%

The data is collected from Agricultural Statistics and Yearbook, Council of Agricultural, Executive Yuan, R.O.C., 2008.

Table 2. The variation of crop production in period of 1992-2008.

Year	Total Production (ha)	Ratio (%) Vegetable
1992	142,312,811	21.74
1993	157,523,597	19.82
1994	160,263,443	18.35
1995	168,517,511	20.35
1996	172,781,410	21.17
1997	173,744,104	20.89
1998	163,618,674	21.75
1999	170,523,785	23.43
2000	165,214,487	23.34
2001	160,758,570	22.87
2002	151,853,269	23.26
2003	147,274,670	23.52
2004	162,300,578	25.09
2005	162,630,935	26.21
2006	172,691,533	25.49
2007	168,368,459	27.90
2008	179,108,569	27.09

The data is collected from Agricultural Statistics and Yearbook, Council of Agricultural, Executive Yuan, R.O.C., 2008.

The data is collected from Agricultural Statistics and Yearbook, Council of Agricultural, Executive Yuan, R.O.C.

The production and marketing of vegetables are monitored continuously by the Council of Agriculture (COA)/Agricultural and Food Agency (AFA) for the purpose of regulating market supply and price, especially in the conditions of abnormal fluctuations in prices and supply in rainy spring and typhoon season. Vegetable soybean, spinach, head lettuce, short-term leafy vegetables, melons and mushrooms are vegetables in high daily demand by the consumers. The government promotes vegetable protective cultivation of green-house structure and the technique of the integrated pest management to ensure the stable supply in quality and safety produce. The application of grading system, with improved packaging and post-harvest techniques, facilitates the export of vegetables, such as lettuce, carrot and cabbage, to neighboring countries.

Regarding to vegetable trade, the import quantity and value of vegetable products were increasing by year, from 1992 to 2008 the quantity increased from 171.8 thousand tons to 417.7 thousand tons and the value increasing three times, from 96 million US dollars to 264.3 million US dollars. But the export quantity decreased from 204 thousand tons to 66 thousand tons and the value decreased from 299.6 million US dollars to 112.7 million US dollars, from 1992 to 2008 (Table 3).

Table 3. The statistics data of trade on vegetable products in the period of 1992-2008.

Year	Import		Export	
	Weight (ton)	Value (1,000 USD)	Weight (ton)	Value (1,000 USD)
1992	171,857.07	96,106.64	204,556.66	299,636.10
1993	197,366.18	100,255.56	169,720.74	263,652.80
1994	235,563.30	111,117.41	152,789.66	222,918.09
1995	212,692.19	116,959.93	161,984.48	213,172.45
1996	231,261.88	139,309.10	152,662.87	184,483.60
1997	260,818.27	158,742.60	115,533.05	151,636.00
1998	302,413.73	163,948.90	91,053.81	128,071.80
1999	297,235.06	169,418.80	112,406.40	134,146.80
2000	303,333.52	170,468.00	105,592.34	131,191.80
2001	336,461.53	166,907.20	85,464.37	109,116.40
2002	321,596.47	172,911.10	81,029.67	98,194.50
2003	239,012.96	170,876.50	80,405.07	104,389.80
2004	340,039.84	184,107.20	88,153.75	113,311.50
2005	466,210.19	236,487.60	76,950.78	97,587.30
2006	421,950.99	217,801.80	66,500.38	94,016.60
2007	473,245.01	239,654.50	59,674.98	87,734.90
2008	417,723.25	264,284.70	78,470.41	112,753.70

The data is collected from General Bureau of Tariff, Ministry of Finance, R.O.C.

The Supply System and Cold Chain of Vegetables Marketing

Agriculture is vital and multi-functional. It serves all facts of human life and is an integral part of environmental conservation and culture. However, agriculture is facing a series of global challenge today. According to statistics and other scientific evidence, global temperature and sea level will raise, and frequency of extreme weather conditions will also increase. These global changes will bring in great impacts on agriculture production and threaten food security.

Climate of Taiwan has both subtropical and tropical types, and the meteorological phenomena are unstable. The natural disaster includes monsoon, typhoon, cloudburst, high temperature, high humidity and cold current, which often attack this island. Due to the climatic characteristics, the agricultural disasters often happen, and high temperature becomes the main restricting factor for cultivating vegetable crops.

In Taiwan, vegetable production is unstable in rainy spring and summer seasons and is over supply in winter time. Developing cold chain system provides high quality, safety, convenience and stable vegetable supply. There are two major pathways of vegetable marketing. Traditionally, vegetables are transported from growers at growing area to wholesale markets, and auction markets are nearby the consuming city, and then transported to retailers (Fig.1). For the purpose to keep product quality, it is necessary to shorten the transport time. To ensure the products arriving convention retail market in early morning and reaching to consumer's refrigerator in 24 hours, vegetable is always transported in the midnight for auction.

About 45% of vegetables are sold through the traditional channels. Because of the distance from southern to northern Taiwan is short, most vegetables can be kept well due to these prompt transportation. The quality of vegetables is maintained by such a good short time and direct transportation.

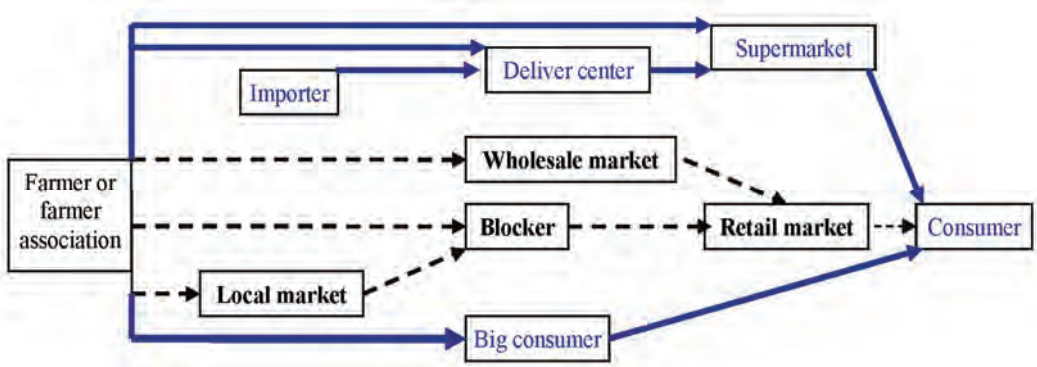

Fig. 1. The vegetables supply system of Taiwan. The solid line means the supply by cold chain.

Another way is to supply for supermarket and hypermarket. In this system, cold chain vegetable is widely accepted, and vegetables are also sold to big group, like military, companies, and schools, etc. Cold chain management for vegetables can reduce post-harvest loss and keep better quality, especially for highly perishable vegetables such as leafy vegetables. Theoretically cold chain system for vegetables should be widely applied. At present, only about 30-40% of vegetables are sold through this system.

Various kinds of practices are used in cold chain operation, especially for horticultural crops. Different practices are adopted for different situations, depending on vegetable properties, available facilities, and consumer's demands. Post-harvest handling is a very important step for most horticultural products prior to shipping and marketing. Among them, the use of "pre-cooling" technique has greatly improved vegetable quality. Pre-cooling is a very important step in cold chain operation. The facilities and techniques include hydrocooling, room cooling, forced air cooling and vacuum cooling.

Low-temperature storage is well-used in cold chain management. The use of "controlled atmosphere" storage (CA storage) provides a chance to prolong the storage life of cabbage and other vegetables. In this system, the suppliers, such as supermarkets, can keep vegetable quality stable in quantity. However, the supply and price of vegetables from growers or wholesale market are often fluctuate when climate change unexpectedly. Short term storage of leafy vegetables is commonly used by farmers' associations. Long term storage for certain seasonal vegetables, such as onion and cabbage, is more professional

Newly Supply Choice – "Fresh-cut" Vegetables

Fresh-cut vegetables are easy to become spoiled. The procedure for producing fresh-cut vegetables is very complicated to keep the product fresh and away from microorganism contamination. Among the products, fresh-cut vegetables need the most precise control in all steps of operations. Shredding and slicing cause damage to vegetables tissues.

In addition to keep fresh-cut vegetables fresh, safety control in microorganisms' contamination is also important. Processing operations such as cutting cause damage to vegetable tissues and lead to leakage of nutrients and cellular fluids providing opportunities for microorganisms' contaminations. The microorganisms may result in a public health problems caused by food borne disease, especially for the fresh-cut vegetables like salad which are consumed without cooking.

The other choice is frozen vegetable, which has been developed for 30 years in this place and not only supply for domestic market but also for export to Japan. According to the modern consumption habit, consumers need more fast and safety food, and frozen vegetable now becomes more popular in the supermarket, especially when the vegetable price arises.

Vegetable Adjustment Measures in Taiwan

For improving marketing efficiency, the Agency of Food and Agriculture (AFA) helped wholesale market to enrich trade facilities, increase service quality and develop shared software. Government assists farmers' associations establishing cold-chain for domestic agricultural production, enhancing their supermarket operations, increasing its cooperation with direct sale channels, such as supermarkets, hypermarkets or consumers who booking large orders.

For vegetable shortage problems caused by natural disasters such as typhoons and extremely rainfall in summer, the AFA assists farmers' associations to establish large scale refrigeration facilities for storing long-term vegetable like cabbage and Chinese cabbage. The storage product will be released to Taipei Wholesale Market when local markets are shortage of supply and/or when market price has abnormal fluctuation. The market-regulate measures implemented by government are listed as followings:

A. Storage facilities improvement

Carefully select the qualified farmer groups, and help them to improve their refrigeration facilities and the marketing ability.

B. Restore measures

Disaster relief and vegetable restore are implemented shortly after the occurrence of natural disasters. Technical and financial assistance for shortening period of leaf vegetable replanting are offered to meet market vegetable demand as early as possible. The replant vegetable can compensate market shortage until it restores to the original quantity in 15 days.

C. Emergency measures

The government will release storage vegetables to compensate for the shortage caused by natural disaster. The government collect weather forecast information continuously and take measures to prevent disasters. The government also monitors crops damage condition and fluctuations in vegetable prices during the period of natural disasters.

AFA will inform the agricultural groups who are taking part in the storage program to release vegetable, when there is AFA showing abnormal fluctuations in prices and supply of vegetable.

Conclusion

Abnormal climate and extreme weather cause the shortage of vegetable in Taiwan. Cold chain system for vegetables is an advanced post-handling system compared to the traditional marketing channels, which helps to expand the vegetable preservation life. However, many factors may restrict the application of cold chain system. These factors include increased cost, complicate

facilities and treatment techniques, high investment and management, and competition from other marketing channels. The main competitions are low cost, easy to handle and high quality channel which is achieved by prompt and short time transportation.

In addition, high quality cold chain system provides products with more stable supply, high convenience and safety than other marketing system. For sustainable operation of cold chain system, farmers' associations build large refrigerators and establish a more efficiency supply system. An integrated management is needed for better control in supply, treatment of products, operation in packing house, and stable outlet. Government will continue efforts on collecting supply and market information, improve techniques and facilities for vegetable production and handling, and develop new products.

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The Agricultural Survey and Postharvest Handling Research of Avocado In Taiwan

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Abstract

The technology for improving postharvest handling from growing field to consumers has been the major subject of detailed research for over a century. The cost for harvest and postharvest up to 30% to 60% of all production and marketing system during horticultural produce, and significant quality loss due to improper processing. Technologies involved in handling, packaging, precooling, transportation, which would minimize losses, maintain high quality, and enhance value-added for horticultural crops that had been extensively applied in Taiwan. For example, precooling is the most common practice, and forced air cooling and vacuum cooling are widely adapted. In this article, information of current postharvest technology in Taiwan, including value, production, and planted area of fruits and vegetables, will be discussed. Avocado is a developing fruit in Taiwan. Postharvest methods of avocado have been tested, including storage temperature, storage period, the effect of ethylene absorbent and the effect of ethylene inhibitor. By some of these methods, avocado can be maintained in good appearance and quality.

Introduction of Taiwan's Agriculture and Postharvest Handling of Fruits and Vegetables

The total population of Taiwan is about 23.1 million people in 2009. The agricultural employed population is 543 thousands, with male population of 70.02% and female of 29.98% in 2009. The gross domestic production (GDP) is 383,343 million USD in 2007 and 402,616 million USD in 2009. The gross national production (GNP) per capita is 17,252 USD in 2007 and 17,651 USD in 2009, according to the statistic table from Directorate-General of Budget. Taiwan's GNP is predicted inceasing to 18,565US$ in 2010. The gross domestic product based on purchasing-power-parity (PPP) per capita GDP from 1980 to 2009 is from 4,000US$ to 29,000US$ (Fig. 1).

The industrial origin of gross domestic product is 417,089 million USD in 2009 and agricultural industry shares almost 1.55%. The composition of crop products in agricultural production is 5960.6 million USD, about 43.9% of total agricultural products, in 2009. Horticultural crops contributed 70.20% of total value of all crops products in 2009 (Table 1 and Fig. 2). Fruit crops and vegetable crops are the most important, 26.59% and 36.75%, respectively, of all crops. In Taiwan, consumers usually buy fresh fruits and vegetables in the markets.

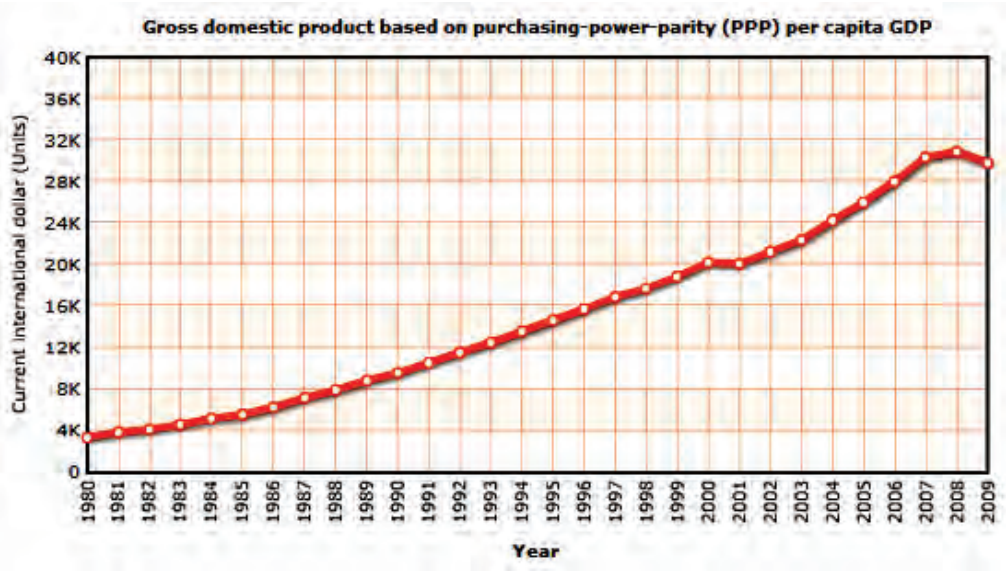

Fig. 1. The GDP based on PPP per capita GDP.

Table 1. The composition of crop products in agricultural production from 2006 to 2009

	Value				Percentage			
Item	2006	2007	2008	2009	2006	2007	2008	2009
Crop production	5756384.4	5612282.0	5970266.7	5960575.0	45.81	43.36	42.90	43.92
Rice	979330.7	869711.4	1045424.9	1125833.8	7.79	6.72	7.51	8.30
Coarse grain	266627.7	209165.1	243573.8	252228.5	2.12	1.62	1.75	1.86
Special crops	270584.8	262651.7	276142.7	280557.9	2.15	2.03	1.98	2.07
Vegetables	1467589.5	1565726.4	1617134.9	1585602.4	11.68	12.10	11.62	11.68
Mildew	99361.4	106380.3	122089.1	118068.3	0.79	0.82	0.88	0.87
Fruits	2255521.5	2186511.6	2271561.3	2190244.3	17.95	16.89	16.32	16.14
Flowers	417368.8	412135.5	394340.0	408039.7	3.32	3.18	2.83	3.01

Note: the production unit is ton.

Taiwan has a mild climate, allowing the production of fresh fruit and vegetables throughout the year. More than 100 different kinds of vegetables are grown as well as various kinds of fruits are planted and cultivated. The major vegetables and fruits species are listed in Table 2 and Table 3. At the same time, owing to climate tends to be warm and humid, it has taken great efforts to reduce postharvest losses to their present level of 10% for both vegetables and fruits (FAO/ Food Balance Sheet). In order to maintaining high quality of fresh produce, cold chain system has been applied since 1960 in Taiwan. At present lots of vegetables and fruits are sold through this system.

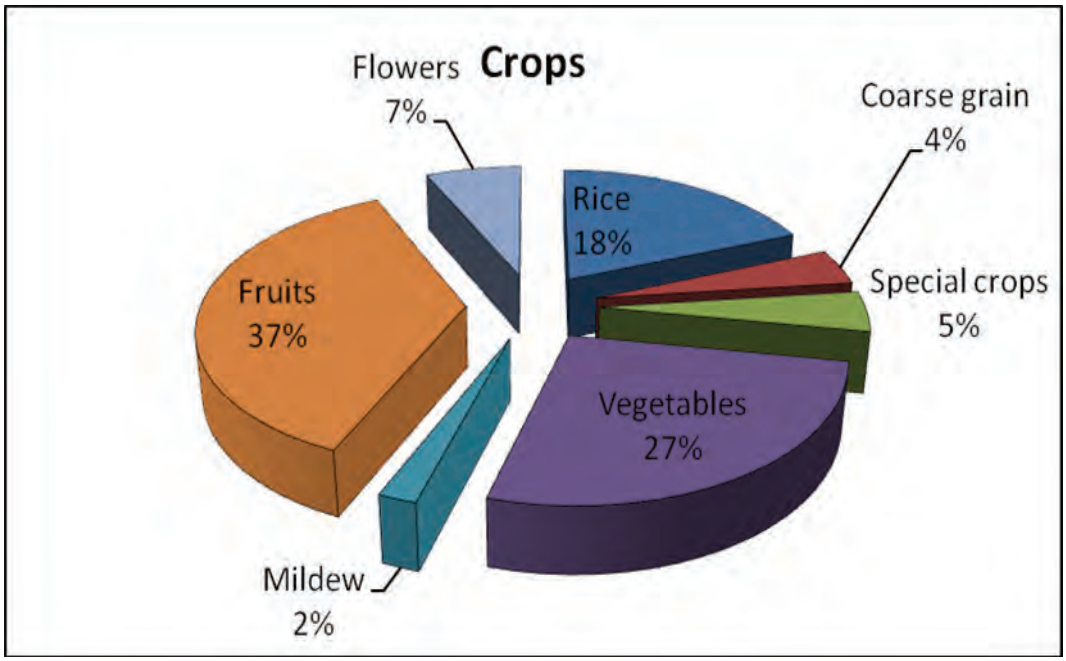

Fig. 2. Fruits crops and vegetable crops are 26.59% and 36.75%, respectively, of all crops.

Table 2. The value, production and planted area of major fruits in Taiwan in 2009

Species	Value (1000US$)	Production (MT)	Planted area (ha)
Citrus	6853533	458813	24062
Pineapple	6238070	434769	11236
Mango	5064466	140290	17130
Pear	5079179	153450	8132
Grape	4311093	98091	3225
Banana	4400020	172550	12349
Longan	2663917	82602	11790
Sugar apple	2885177	70370	5987
Lychee	3113723	95440	12015
Guava	2739882	135303	7225

Table 3. The value, production and planted area of major vegetables in Taiwan in 2009

Species	Value (1000US$)	Production (MT)	Planted area (ha)
Bamboo shoot	230154.7	251994	27045
Other leafy vegetables	126681.4	242723	17556
Cabbage	109660.8	346297	8371
Scallion	96500.4	111347	5368
Watermelon	81244.6	217619	11925
Garlic bulbs	74399.9	49600	5477
Tomato	67985.4	99491	4104
Water bamboo	60789.4	46169	2057
Cauliflower	46068.8	76569	2976
Muskmelon	24840.0	26147	2099

However, extended cold storage always result in physiological disorders and abnormal fruit ripening, reducing consumer acceptance. In many commodities the severity of chilling injury (CI) increases when the fruit is refrigerated for prolonged periods at close to 0℃, but above fruit freezing point. These symptoms are important to commercial business since shipping of fruits to distant markets and storage before selling. In the past report of Taiwan, the guava symptoms of chilling injury appeared when fruits were stored at 1℃ to 5℃ for a period of 7 to 12 days and then placed at 20 to 25℃ for 3 days. Guava fruit shows that abnormal ripening, pulp browning and water-soaking core, and the data suggest that 5℃ to 10℃ is the appropriate temperature for storage. For this reason, several physiological and physical researches of fruits and vegetables preventing chilling injury and other storage methods are developed. Furthermore, extension storage life and export horticultural products to markets in other country are always the continuously pursue goal of the industry.

Postharvest Handling of Avocado in Taiwan

Introduction

Avocado (*Persea Americana* Mill.), which has been referred as the most nutritious of all fruits, has worldwide recognition and significant volume in international trade. The unique fruit has been appreciated and utilized for at least 9,000 years in and near its center of origin in Meso-America. It is a polymorphic tree species that apparently originated in a broad geographical area stretching from the eastern and central highlands of Mexico through Guatemala to the Pacific region of Central America. Avocado produced a green-skinned, pear-shaped fruit that ripens after

harvesting, and is partially self-pollinating and often is propagated through grafting to maintain a predictable quality and quantity of the fruit.

Ecological races and adaptations

There were three distinct ecological species of avocado: The Mexico, Guatemalan and West Indian races. The Mexico species is grown at high elevated (1400-2500m) and cooler (14-19.8℃) areas, with rainfall from 600 to 1600mm and a half year dry season from winter to spring. The Guatemalan species is grown in the less extreme conditions. They are common in tropical highlands with all year-round cool conditions. The West-Indian avocado species is grown in lowland and in hot and humid Central American forests with a short dry season.

World production and fruit composition

Total world avocado production increased approximately 3.3- fold over 35-year period, from 697,869 tons reported from 76,770 ha in 1961 to 2,303,389 tons harvested from 339,141 ha in 1996. According to FAOSTAT Database, Mexico is the country that producing the most avocados around the world, Indonesia is the second, and the United States of America is the third (Table 4).

The data is collected from FAO statistic database

The avocado fruit is a traditional staple in Guatemala and nearby countries, the daily food of the labouring individual. It is also an ingredient of widely consumed for traditional foods. In some countries the fruit is eaten with sugar, in ice cream or mixing with milk. Avocados are high in valuable fats and appear to have a beneficial effect on blood serum levels. Avocados also have 60% more potassium than bananas, and rich in vitamins B (Table 5).

Table 4. The avocado production countries

Rank	Country	Produciton Value (US 1,000)	Production (MT)
1	Mexico	668,586	1,040,390
2	Indonesia	169,381	263,575
3	United States of America	137,523	214,000
4	Colombia	119,408	185,811
5	Brazil	112,460	175,000
6	Chile	104,749	163,000
7	Dominican Republic	89,968	140,000
8	Peru	65,548	102,000
9	China	54,624	85,000
10	Ethiopia	52,374	81,500

Table 5. The nutritional value per 100g avocado fruit

Item	Avocado, raw (edible parts)
	Nutritional value per 100 g (3.5 oz)
Energy	670 kJ (160 kcal)
Carbohydrates	8.53 g
Sugars	0.66 g
Dietary fiber	6.7 g
Fat	14.66 g
Protein	2 g
Thiamine (Vit. B_1)	0.067 mg (5%)
Riboflavin (Vit. B_2)	0.130 mg (9%)
Niacin (Vit. B_3)	1.738 mg (12%)
Pantothenic acid (B_5)	1.389 mg (28%)
Folate (Vit. B_9)	81 μg (20%)
Vitamin C	10 mg (17%)
Magnesium	29 mg (8%)
Phosphorus	52 mg (7%)
Potassium	485 mg (10%)
Zinc	0.64 mg (6%)

Percentages are relative to US recommendations for adults. (Source: USDA Nutrient database).

Research of postharvest handling of avocado in Taiwan.

In Taiwan, there are about 875 ha planted with avocado trees, and is considered as a new growing fruit industry. Avocados was imported first time in 1930. The avocado fields are spreaded in Chiayi and Tainan counties. The objectives of the research were to search for the most suitable storage conditions of the 'CASE3' avocado fruits, which is a popular variety in Taiwan and bred by TARI. The shape of 'CASE3' fruit is like pear and seed is middle size. The fresh weight, seed weight, dry matter content and crude fat content of 'CASE3' avocado fruits increased with the delaying of harvest date. Its major harvest season is from August to October.

The effect of different storage temperature and storage period to the fruit quality

The ripening quality of 'CASE3' avocado fruits are influenced by storage temperature and time. High temperature will induce rotten while low temperature will induce chilling injury. In order to know the effect of storage temperature and storage period of 'CASE3' fruit quality, fruit were stored at different temperatures at 1, 3, 6, 9, 12, 15℃ for 2, 4, 6, and 8 weeks, respectively.

After storage, fruits were treated with Ethrel (diluted 1000X) for 12 hours and stored at 25℃, 85% RH to observe the change of their quality. of fruit. The result (Fig. 3, Table 6) shows that 'CASE3' avocado fruits stored at 1℃and 3℃ after two weeks would exhibit chilling injury (CI) symptom, as peel color change abnormally and pulp could not soften normally. Fruit pulp stored at 6℃ after 8 weeks might soften, but fruit pulp mostly become brown The fruit produced fetid odor and lost the edible value. Fruit pulp which stored at 9℃ after 4 and 6 weeks could soften normally, and the color of pulp was in normal yellow. The fruits stored at 12℃ after 4 weeks would be soften rottenly, similar result at 15℃ after 2 weeks storage. These results indicate that optimal storage temperature for 'CASE3' avocado fruits is 9℃ and the fruit could ripen normally without pulp browning after storage for 6 weeks.

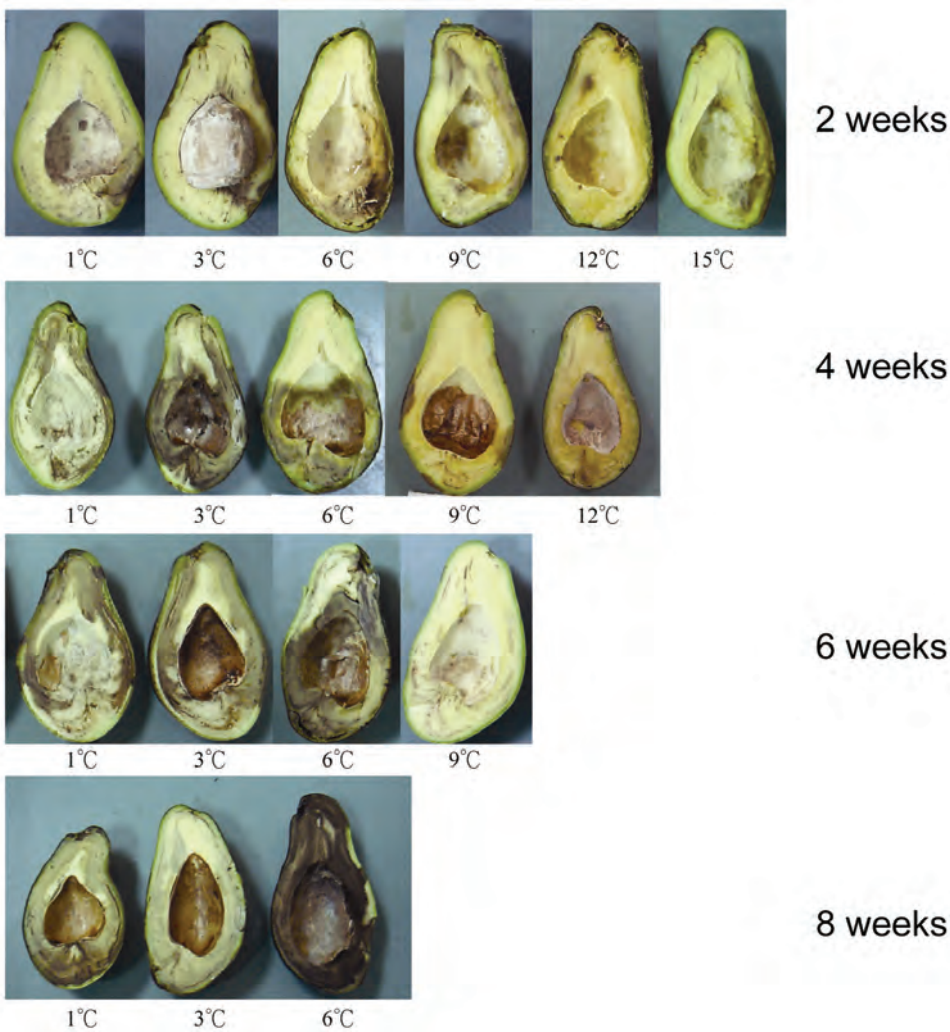

Fig. 3. The fruits of “CASE3” avocado stored at1, 3, 6, 9, 12, 15℃ for 2, 4, 6, and 8 weeks, respectively. (Source: Dr. Ching-Chang Shiesh)

The influence of ethylene absorbent on avocado fruit

The avocado (*Persea americana* Mill.) is a climacteric fruit that is characterized by a surge in ethylene production at the onset of ripening. This climacteric increase in ethylene production is associated with hastened ripening. Avocado is one of the most rapidly ripening fruits. It often ripen completely within 5 to 7 days after harvest.

To know the influence of ethylene absorbent on avocado fruit, ethylene absorbent was put in the PE bag with fruits stored at 9℃ for 2 months. After the fruits were treated with Ethrel (diluted 1000X) for 12 hours and stored at 25℃, RH:85% to observe the quality of fruits, color of pulp and peel turn brown and pulp became soft after four days of treatment. The fruits treated with ethylene absorbent maintained normally in peel color and pulp firmness.

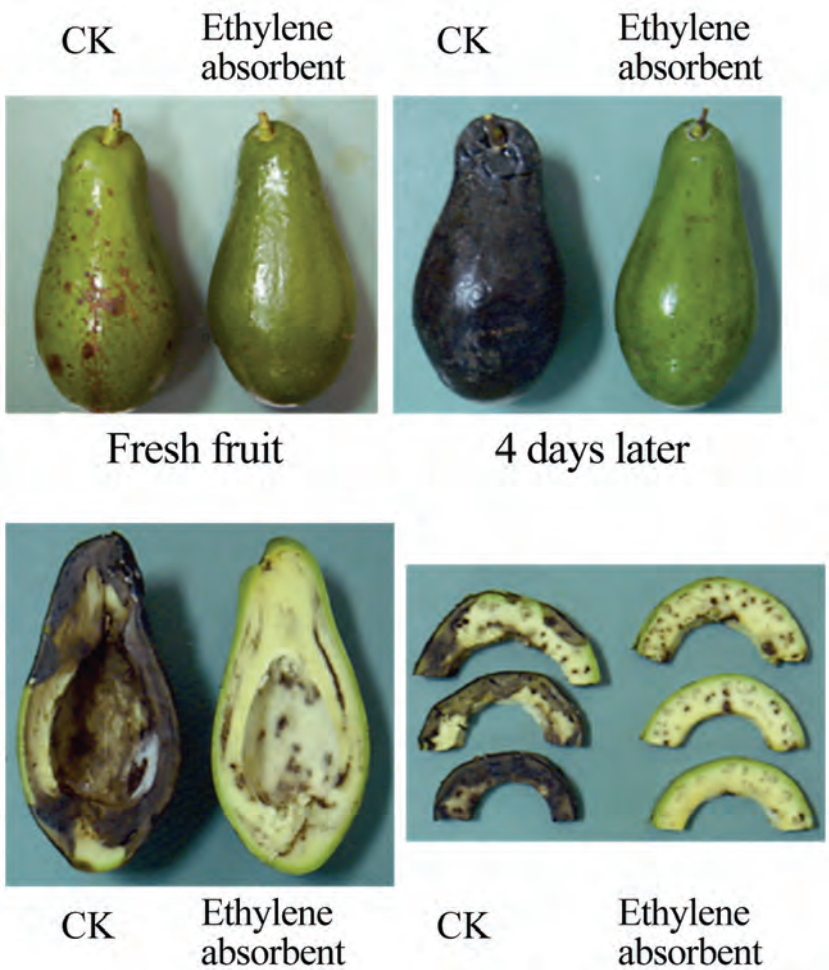

Fig. 4. The effect of ethylene absorbent on avocado fruits 4 days after storage at 9℃ for 2 months and Ethrel treatment. (Source: Dr. Ching-Chang Shiesh)

Table 6. The pulp firmness of "CASE3" avocado fruit stored at 1, 3, 6, 9, 12, 15℃ for 2, 4, 6, and 8 weeks, respectively

Storage temperature	Pulp firmness (N) Storage time			
	2 weeks	4 weeks	6 weeks	8 weeks
H	26.6 a[z]	26.6 b	26.6 b	26.6 b
1℃	3.9 b	131.0 a	261.8 a	199.8 a
3℃	3.1 b	115.6 a	238.8 a	214.7 a
6℃	0.3 b	12.1 b	5.3 b	5.3 b
9℃	0.0 b	3.4 b	6.6 b	--
12℃	0.0 b	0.0 b	--	--
15℃	0.0 b	--	--	--

[z] Means with same letters within a column are not significantly different by Duncan's Multiple Range Test at 5% level.

[y] H=evaluated after ripening at 25℃ for 4 days, no stored.

Table 7. The influence of ethylene absorbent on pulp color and pulp firmness

Treatment	Pulp color					Pulp firmness (N)
	L	a*	b*	C	H	
CK	35.4 b[z]	9.1 a	15.3 b	18.0 b	58.1 b	26.7 a
Ethylene absorbent	67.7 a	2.6 b	41.8 a	42.2 a	85.7 a	6.6 b

[z] Means with same letters within a column are not significantly different by Duncan's Multiple Range Test at 5% level.

The influence of ethylene inhibitor (1-MCP) on avocado fruit

1-MCP (1-methylcyclopropene) has been shown to delay ripening and improve storage quality of climacteric fruits including avocado. 1-MCP and fruit was both put in a 0.03 mm thickness PE bag. In control the fruit was put in PE bag without 1-MCP. Then they were stored at 9℃ for 4 to 6 weeks. After storage, they were treated with Ethrel (diluted 1000X) for 12 hours and kept at 25℃, 85% RH for 4 days to observe the quality of fruits. In Table 8 , the peer color of fruit treated with 1-MCP has higher L , b*, C and H value. The a* value is -8.2 compared to the control with a value of 7.5. The peer color without 1-MCP turn red while the peer color of 1-MCP treatment maintained normal green. The pulp color of fruit of 1-MCP treatment is better than control. Both of them have high firmness. On the other hand the respiration rate and ethylene production rate of fruits treated with 1-MCP are higher than control after have treated with Ethrel (Table 9).

Table 8. The effect of 1-MCP treatment on the peel color and pulp color of avocado fruits.

Treatment	L	a*	b*	C	H
Peel color					
CK	32.7	7.5	17.7	20.1	63.7
1-MCP	47.3	-8.2	35.6	36.5	102.7
Treatment	L	a*	b*	C	H
Pulp color					
CK	66.9	-0.6	42.4	42.6	90.5
1-MCP	71.5	-2.2	46.3	46.4	92.4

Table 9. The respiration rate, ethylene production, and firmness of avocado fruits after treated with 1-MCP.

Treatment [z]	Respiration rate ($mlCO_2$/kg-hr)	Ethylene production rate (μl C_2H_4/kg-hr)	Firmness (N)
CK	115.0	1.6	8.4
1-MCP	122.7	90.5	110.7

Conclusion

Many countries wish to export their products to other countries. Difficulty exists in passing the quarantine requirements imposed by importing countries. The development of more advanced technologies on this purpose should be emphasized and proceeded continuously. Until now, high quality, safety, and good appearance become more important at present and future. Recent progress has been based on good cooperation between postharvest scientists and government coordinators. It helps in improving the quality of fresh produce at the markets. Farmers can get the benefits from reduced postharvest losses and increased value-added products.

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114-124

Technology on Reducing Post-harvest Losses and Maintaining Quality of Fruits and Vegetables in India

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Abstract

Fruits and vegetables are highly perishable in nature. A considerable amount of these commodities produced in India is lost due to improper postharvest operations; as a result there is considerable gap between gross production and net availability. Post harvest loss reduction is essential to make available more food from the existing level of production. The losses can be minimized by following simple management practices, such as, sorting and grading, pre-cooling, suitable packaging, proper handling, storage and supply chain management. Therefore, to achieve the target of feeding the growing population as well as meeting the requirements of the processing industry and export trade, only increasing the production and productivity will not be enough. A lot more emphasis needs to be given to post harvest management and maintaining quality of these highly perishable crops.

Introduction

India being a home of wide variety of fruits and vegetables holds a unique position in production among other countries. The diverse agro climatic conditions in the country make it possible to grow almost all varieties of fruits and vegetables. Recent economic growth and changes in dietary patterns have made both the production and consumption of fruit and vegetables increasingly important. The fruit and vegetable sector has a vital role in farm income enhancement, poverty alleviation, food security, and sustainable agriculture. This sector plays a significant role in Indian agriculture. The contribution of horticultural crops towards agricultural output and export earning of total agricultural produce is very high considering the percent area covered by these crops. The horticulture sector contributes around 28% of the GDP from about 13.08 % of the area and 37% of the total exports of agricultural commodities in the country. Although India is a major producer of horticultural crops, many Indians are unable to obtain their daily requirement of fruits and vegetables, a considerable amount of fruits and vegetables produced lost due to improper post harvest operations; as a result there is a considerable gap between the gross production and net availability. Furthermore, only a small fraction of fruits and vegetables is utilized for processing compared to other countries.

India with its current production of around 62.8 million MT, accounts for about 11% of the world's fruit production. The area under fruit crops in India is 5.81 million ha with a production of 62.86 million tons. Among the horticulture crops, at present fruits crops recorded a two folds increase in area and production as compared to 1991-92. India occupies first place in the production of mango, banana, papaya, pomegranate, sapota, aonla and acid lime. About 39% of the world mango and 23% banana are produced in the country. Major fruit producing areas are distributed in subtropical and tropical parts of the country and a limited area has been harnessed in the temperate region. It is a matter of great concern that approximately 25 to 30% of fruits are lost during transit and storage, highest being about 40% in banana followed by mango. As a result the net quantity reaching the consumers is about 90 g of per capita availability daily as against a recommended consumption of 120 g per capita/ day. One of the factors aggravating post harvest losses of fruits which are seasonal and perishable is the utilization of very meager quantities for processing. Less than two percent of total fruits are processed for various products.

India has emerged as the second largest producer of vegetables with a total estimated production of 122.26 million tons from an area of 6.15 million ha with productivity level of 15.82 ton per hectare. In the last one and half decade, country's vegetable production has almost doubled and gross vegetable productivity of the country by one and half times. Presently, India's share is 11% of total world production of vegetables. But less than 2% of the total vegetable production in the country is commercially processed as compared to 70-80% in developed countries. Major contribution to vegetables comes from potato, tomato, brinjal, okra, beans and cucurbits. India is the first in cauliflower production, second in onion production and third in cabbage production in the world. Still, per capita availability of vegetables is 190 grams against the requirement of 280 grams.

Present Status of Post Harvest Technology in India

India has a strong in horticulture production base. However, among other things, the lack of a modern supply chain including cold chains has prevented this strength from being fully leveraged either for exports or for processing. As a result India has a little over 1% share of global fruit and vegetable exports despite having over 10% of the world's production of fruits and vegetables. At the same time, considerable postharvest losses occur in fruits and vegetables, owing to the lack of suitable harvesting equipment, collection centers in major producing areas, suitable packing containers, commercial storage facilities, a cold chain and proper transportation systems. Losses in fruits and vegetables are estimated about 30% due to mismanagement, valued at nearly Rs. 13600 core in fruits and Rs. 14100 core in vegetables annually depending upon the fruit variety and the postharvest handling system. Spoilage of fresh produce is also accelerated by the hot and humid climate of the region.

The small farmers lack resources and are unable to market their produce and implement suitable postharvest handling practices. Therefore, to achieve the target of feeding the growing

population as well as meeting the requirements of the processing industry and export trade, only increasing the production and productivity will not be enough. A lot more emphasis needs to be given to post harvest management and maintaining quality of these highly perishable crops. The only way to cope with the present situation is to give a massive thrust to post harvest loss reduction in order to make available more food from the existing level of production. To achieve the target we shall have to adopt advanced technology in our post-production system of horticultural produce. The detailed analysis of current status of post harvest technology in India is as under:

New Initiatives for Development of the Sector

In past few years, considerable emphasis has been given to the production of horticultural crops in India. There is sharp increase in budgetary allocation in horticulture sector from IV to X plan i.e. 1700 times for research and 5800 times in respect of development programmes. At present the programmes related to horticulture crops form approximately 30 percent of the total outlay of agriculture development of the Department of Agriculture & cooperation. Five new development programmes launched during the X plan namely; Technology Mission for Integrated Horticulture Development in North-East region & Himalayan States, National Horticulture Mission, National Mission on Medicinal Plants, National Bamboo Mission and Micro Irrigation Mission to achieve the transformation of horticulture utilizing the technology. These programmes have been invested Rs. 2400 crore during X plan and continuing during XI plan with budgetary support of Rs. 14134 crore for overall development of Horticulture sector with end to end approach.

The efforts in the investment have been rewarding and the area under horticultural crops has been increasing. The increase in area which was 2.3% and 2.43 %during the VIII and IX plan significantly went up to 6.6% in the X plan. Accordingly, the area under fruits from 3.8 million hectares in 1999 has increased up to 5.81 million hectares in 2008 with an increased production of about 20 million tons. The area under vegetable cultivation also showed a similar increase of 1.85 million ha from 1999 to 2008 with an increased production of 34.67 million tons.

The new schemes are having provision of financial assistance for establishment of post harvest infrastructure to increase marketability of horticulture produce, adding value to produce, increasing profitability and reducing losses. Different post harvest activities like establishment of pack houses, pre-cooling units, mobile pre-cooling units, cold storage units, controlled (CA) storage,/ modified atmosphere (MA) storage, refrigerated vans/ containers/ mobile processing units, ripening chambers, evaporative/ low energy cool chambers, preservation units, onion storage units and zero energy cool chambers etc. being supported under the schemes. To induce investment from private sector in marketing related activities provision of assistance for wholesale markets, rural markets/ apni mandi and retail markets, static mobile vending cart platform with cool chamber etc. have also been made under National Horticulture Mission.

Infrastructure for Technology Development

Horticulture research in India received a boost with the establishment of Indian Institute of Horticulture Research Institute, Bangalore in 4th five year plan (1969 to 74). Rapid expansion of horticulture research infrastructure took place in 7th and 8th plans. Today India has dedicated research infrastructure by way of 10 central Institutes with 27 regional stations, two full fledge State Universities on Horticulture (each in Himachal and Andhra Pradesh), 28 State Agricultural Universities and 15 central/general/deemed to be universities with Horticulture discipline.

Postharvest research is currently conducted mainly by the CFTRI, Mysore, CIPHET, Ludhiana, RRL, Jammu and BARC, Mumbai, CSIR laboratory, Palampur and the DFRL, Mysore. Relatively little emphasis was given to research and postharvest technology in the ICAR system until the late seventies. An All India Coordinated Research Project on Postharvest Technology (AICRP) of horticultural crops was started by the ICAR in August 1978 and four centers in the country (IARI, New Delhi; CMRS, Lucknow; IIHR, Banglore and YSPUHF, Solan). During the 6th plan the AICRP (PHT) was continued by the ICAR and was strengthened by adding four new centers, i.e., TNAU, Periyakalam, KKV, Dapoli, HAU, Hisar and ICAR-RC, Shillong during 7th and 8th plans, four more centers were added, i.e., BCKVV, Kalyani; MPKVV, Rahuri and RAU, Pusa, Bihar, bringing the total to 11 centers under the project.

Packing Stations

Pack houses have sorting, washing, grading, packaging and labeling facilities in addition to pre-cooling. In most of the growing areas, there is lack of the concept of establishing packing stations in India. Fruits and vegetables are generally packed in the field without any pretreatment. In absence of packing station concept, large volumes of the inedible parts of fruits and vegetables are transported to the markets from the field. This increase the cost of transportation and inedible parts ultimately cause sanitation problems.

Recently, several modern pack houses have been established with washing/ cleaning, sorting, grading, waxing, and packaging facilities for fruits and vegetables in the country. National Horticulture Mission, National Horticulture Board and APEDA supported pack house activities by providing financial assistance for establishing these facilities for fruits and vegetables. In modern pack houses most of these operations are done automatically under a cooled house. Belt conveyor conveys the materials form reception to a jet washer. Jet washer removes the dirt and cleans the surface under forced jet of water. After this the produce is graded into three to four grades based on size by power operated size grader. In some cases surface of fruits/ vegetables waxed with edible waxes to have good appearances and enhances shelf life.

Primary Processing

The minimal processing of fruits and vegetables is an area which offers considerable potential for development of the fruit and vegetable sector. Consumers in metro cities are increasingly

demanding ready to eat fruits and vegetables, with a fresh like quality containing only natural ingredients. This has been mainly due to changing life styles. These changing trends have led to increased demand for fresh cut or ready to eat fruits and vegetables. In addition to convenience, consumers perceive fresh-cut produce to be good value of its freshness, cent percent edible food of high quality nutrition.

Today, minimally processing of vegetables such as cauliflower, peas, leafy vegetables, etc has started at some packing stations immediately after harvesting, through the removal of inedible parts and being marketed in metro city markets in unit packs. Consumer friendly products like frozen green peas, ready to use salad mixes, vegetable sprouts, ready-to-cook fresh cut vegetables are major primary processed retail items. Minimally processed produce, however, deteriorates at a much faster rate than does intact fruits and vegetables. Stringent quality management systems such as Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Point (HACCP) as well as proper packaging and temperature management are, therefore, required to assure its safety and freshness.

Packaging and Transportation

Packaging is an integral element in the marketing of fresh horticultural produce and it is link between the producer and consumer. It requires at both the stages i.e. from field to market and processor to consumer. From field to market traditional forms of packaging such as bamboo baskets, wooden boxes and gunny sacks are still widely used but plastic crates are gaining more popularity as a packaging material for transport of fruits and vegetables. Considerable work has been done by different agencies in introducing alternative types of packaging. The ventilated CFB box which contains ventilated partitions is found ideal for the packaging and transportation of fruits, owing to the comparably minimal level of bruising observed in these boxes.

Packaging provides handling facilities for loading, transport & storage for both the processor and consumer. Modern technology and changes in consumer demand for convenience and packaged foods, have given both for the development of new packaging material, packaging techniques, machinery, graphics, computer design etc. There is an increasing demand for the new specific and innovative packaging techniques for processed foods. India is a fast emerging market for canned fruits and vegetables. Potatoes, cauliflower, tomato are canned in dry either in natural form or curried type using spices.

Cold Storage

Exposure to the high temperature is the biggest factor in the post harvest losses of fruits and vegetables. The ideal condition for storage of fresh fruits and vegetables is the lowest temperature which does not cause chilling injury. This can be maintained by different type of cooling systems. Cold storages have existed in India from decades for storing perishables. India has more than 5000 cold stores with about 22 million metric tons capacity out which 80% are almost dedicated for

potatoes only and about 17% fall under multi commodity category. Surprisingly only 2-3% of its capacity is utilized for storage of other fruits and vegetables. Most of these units do not have facilities to store a wide range of products across varied temperature ranges. Mainly cold stores are designed for storage of potatoes and in similar conditions fruits and vegetables are stored. In addition to this, different types of fruits and vegetables, which are not compatible to each other, are stored together and causes post harvest losses in different form even in the cold store. The technology in use for cold storage has also largely based on the principle of evaporative cooling with the use of diffusers and bunker coils. The last few years have seen replacement of ammonia with Freon.

The major constraints in the development of cold storage industry in India are high capital cost, high electricity tariffs causing increased operational cost, non-adoption of energy efficient technology and non-professional management. Uninterrupted power supply is essential for cold storage facility which is not always available readily. If refrigeration plant is failed even for a small period and temperature of cold stores increased, induce thermal shock to the produce and causes accelerated loss during storage. Cooling operation is generally for quality; however temperature control is also useful to inhibit the growth of pathogenic bacteria. Therefore, stakeholders at both the ends of value chain farmers and consumers must be aware about the benefits of it.

Cold storage activities in India are limited mostly to tuber crops, onion and Cole crops. Spices like chillies and tamarind are stored largely in cold storages. Apple has been chosen as one to build infrastructure around it as it lends itself to longer duration storage of 8 to 10 months when stored under controlled climatic conditions which is limited to a few weeks under ambient storage conditions. Banana and Mango constitute over 50 percent of the total fruits produced in the country. Litchi, grapes, pomegranate, potato, onion, Chillies are another ideally suited crops for cold chain.

Control Atmosphere/Modified Atmosphere Storage

Modified atmosphere (MA) essentially means any deviation from the normal atmospheric gas composition. If this deviation is strictly controlled with certain specific gaseous concentrations of N_2, CO_2 and O_2 then it is termed as "Controlled Atmosphere" (CA). Usually modification of atmospheres during storage of fruits and vegetables involve reduction in oxygen (O_2) and/or elevation of carbon dioxide (CO_2) concentrations. The use of CA/MA should be considered as a supplementary practice to proper temperature and relative humidity management.

The beneficial effects of CA/MA treatments are retardation of ripening, senescence and physiological changes. In addition it helps in reducing the physiological disorders, e.g. chilling injury of various commodities. Modified atmosphere can have a useful tool for control of certain insects. However, there are certain limitations such as irregular ripening, development of off

flavors and stimulation of sprouting etc. if not properly carried out. The design and construction of controlled atmosphere stores require precision control of the system. The controlled atmosphere store has to be relatively gas tight, and fitted with reliable refrigeration system with a means of measuring and controlling the concentrations of both carbon dioxide and oxygen. Now establishment of CA/MA storages have been started in India after having provision of financial assistance under National Horticulture Mission and National Horticulture Board schemes.

Cold/Cool Chain

While India's strength in the horticultural sector has led to a large production base of fruits and vegetables, the enormous amount of wastages (estimated to the extent of 30%) due to inefficient supply chain has prevented the farmers and processors from reaping the benefits. Eliminating field heat immediately after harvest is very important for extending the shelf life and quality of fresh fruits and vegetables. For this, maintenance of cold chain from grower to the consumer is of crucial relevance for maintaining quality of the product. Cold chain refers to a complete set of supply chain involving the production, storage and distribution of perishable products that require temperature control in order to keep the products characteristics, freshness and nutritive values retained for longer duration. This requires control over various factors such as fluctuations in temperature and humidity and impact from incorrect handling across the supply chain.

The cold chain industry in India consists of a dozen large players such as snowman, Frick India, Voltas Ltd, Blue Star etc. that provide services ranging from refrigeration equipments and storage services to integrated logistics. The services being presently provided rarely cover the entire country leading to breakage in cold chain and consequent produce wastages. Cold chain activities in India are fragmented and mostly confined to retail markets and cold storages. The key issues in the agri-logistics related to the development of the cold chain industry are of non-standard pricing, lack of scientific handling of produce and consequent high prices and limited choices for the consumers. The cold chain operators also do not have knowledge about what treatment and handling to accord to which produce and what sort of cold chain configuration is required for which produce. In addition to the above factors, the perishable nature of the commodity class and the fact that the requirement for cold chain varies across each commodity even within the same class makes the task very complicated.

Despite fairly widespread awareness on the need for a strong cold chain network, adoption in India is continues to be low. Although, the recent development of direct retailing in domestic segment has demonstrated the success and utility of captive end-to-end cold chain in India including that of refer transportation. Desai fruits and vegetables in Gujarat, Namdhari fresh in Karnataka, Adani Agrifresh in Himachal Pradesh are some of the few models in private sector in direct retailing with established cold chain to ensure quality of produce. The cold chain not only

helps in enhancing the shelf life but more importantly the ripening chambers help overcome the health issues associated with common ripening systems using carbide. India's rapid economic growth and ongoing consumer boom have contributed greatly to the growth of retail sector The maintenance of low temperatures at different stages of handling by maintaining cold chain helps in reducing losses and retaining the quality of fruits and vegetables...

The requirements for cold chain extend right across the product value chain and can be very complicated depending upon the nature of the produce and the ultimate customer preference. The possible routes of fruits and vegetables in the country may be as under:

I. Harvest- Primary Market Transport- Secondary Market Transport- Processor- Consumer
II. Harvest- Pre-cooling- Packaging- Reefer Transport- Perishable Center Handover- Doc Unloading- Dispatch- Tarmac- Aircraft

Processing

Presently, less than 2% of fruits and vegetables are processed in India. The prominent items processed in fruit and vegetable processing sector are fruit pulps and juices, fruit based ready to serve beverages, canned fruits, and vegetables, jams, squashes, preserve, ketchups, sauces, pickles, chutneys and dehydrated vegetables. The industry has also taken up the processing of frozen pulp and vegetables, freeze-dried fruits and vegetables, fruit juice concentrates, preserved garlic, ginger and onion pastes etc. Development of new products like juice punches, banana chips and fingers, mango nectar and fruit kernel essential oil from citrus, fruit wines, dehydrated products from grapes, pomegranate, mango and coconut etc. are getting popularity day by day.

The number of processing units based on fruits and vegetables and their installed capacity are increasing at a compound growth rate (CGR) of 3.68 percent and 10.04 percent per annum respectively. However, the actual capacity utilization is about 47 percent. Among the components of processed fruit and vegetable products basket, dried and preserved vegetables accounts for the highest at 60 % followed by mango pulp (15%), pickles and chutney (11%) and other processed fruit and vegetables (13%).

The fruit and vegetable processing industry has been faced with the problems of quality raw material, capacity utilization, transfer of technology being difficult due to majority of the units being in cottage and home scale sector. The recent innovations, if properly utilized, would help overcome the problems of marketing.

Marketing

Due to presence of too many intermediaries and concentration of trade in few hands resulting in exploitation of the growers – sellers, the producer's share in consumer rupee is low. However, in view of the increased production of fruits and vegetables and also to sustain the interest of the cultivators and also to motivate them to produce more, it is imperative that they get a reasonably

high price for their produce. It is also essential to identify the best channel of marketing which ensures this.

Pre-harvest contractors (PHC) are found to be predominant in marketing of fruits as about 75% of fruits has been marketed through PHC. Thus, pre-dominance of PHC in fruit marketing is still continuing despite the fact that it is not desirable practice. The studies on vegetables have shown the pre-dominance of commission agents in their marketing and commission charges is one of the major components of marketing costs.

Transformation is taking place in marketing of high value commodities like fruits and vegetables due to globalization and liberalization. Accordingly procurement and distribution system for fruit and vegetables is also witnessing changes in the form of contract farming, growers associations, cooperative marketing and also integration of production and marketing through processing. Of late super markets (Retail supply chain) are entering the fruit and vegetable marketing in a big way.

Quality and Safety

The quality of fruits and vegetables can be defined on the basis of external, internal and hidden attributes. External attributes are size, shape, color, firmness, defects etc. The internal attributes may be aroma, taste etc. Combination of external and internal attributes generally determines the acceptability of fruits and vegetables. Hidden attributes may be wholesomeness, nutritional value (vitamins, minerals, fiber etc,), and safety aspects (natural occurring toxicants, chemicals residues, heavy metals etc.).

Fresh fruits and vegetables are living tissues which are subject to continuous change after harvest. While some of the changes are desirable, most are not desirable from consumer’s standpoint. Grade standards identify the degree of quality in a given commodity that provides the basis for its usability and value. Due to globalization of trade, 32 important fruits and vegetables grade standards have been harmonized with international standards viz; Codex, EC etc. and notified. Grade standards of another 7 fruits and vegetables are at various stages of finalization and notification. This provides recommendations for proper packaging and transport of fresh fruits and vegetables in order to maintain produce quality during transportation and marketing.

In response to consumer concerns, many retailers in various countries require growers to have independent third party inspections of farms to ensure that fruits and vegetables are being grown, harvested and packed using Good Agricultural Practices (GAPs), Good Hygienic Practices (GHPs), Good Manufacturing Practices (GMPs) etc. These programmes have developed rapidly over the past decade and many growing packing operations are being inspected by the agencies approved by the retailers. EUREPGAP/ GLOBAL GAP, Hazard Analysis and Critical Control Point (HACCP), British Retail Consortium (BRC), ISO- 22000 standards, etc. are worth mentioning in this regard.

In India, the farmers generally bring fruits and vegetables to the market without grading and packing. There is need to encourage grading, packing and labeling at farmers level to ensure uniformity and traceability. The cold chain needs to be developed to reduce post harvest wastages and ensure quality and safety of fresh fruits and vegetables. GAPs, GHPs, GMPs and other Food Safety Management Systems need to be promoted amongst farmers and other stakeholders in supply chain to ensure safety of fresh fruits and vegetables.

Modern Processing Techniques

Several new R&D innovations have been made in the field of value addition of fruits and vegetables from different organizations. Some of the new technologies replacing conventional processes are as under:

a. High pressure processing

b. Ohmic heating

c. Microwave heat processing

d. Irradiation

e. Extrusion Processing

The future thrust areas may be oriented towards popularizing these new technologies giving safe packaged large amounts of fruits and vegetables.

Conclusion

The perishable fruits and vegetables need very careful handling at every stage starting from pre-harvest to harvest, sorting, grading, packaging, marketing and storage. For preventing the post harvest losses proper storage, cold preservation, packaging and transport methods with Hazard analysis Critical Control Point (HACCP) norms have to be given more thrust. The cold chain system is effective in reducing postharvest losses in fruits and vegetables. For this infrastructure at proper place and proper time is a key element for post harvest management and value addition of fruits and vegetables. Development of cold chain in rural areas presents the biggest challenge due to lack of existing infrastructure, poor financial strength of the farmers. This can, however, be circumvented through the adoption of an integrated cluster approach involving aggregation of villages in the form of clusters. This can be done in an effective manner wherein infrastructural facilities (pre-cooling and pack houses) can be provided in a pooled manner to the farmers as it would enable risk sharing, improved marketing and market power among producers besides going long way in assuring quality control and economies of scale. Pooling refers to the combination of production from many producers under the marketing skills of a specialized staff.

Most of the fruits and vegetables flow to the primary markets from where they change multiple hands before reaching the ultimate consumer. Lack of facilities along the transportation

route increase the wastage and deteriorate the quality. Hence an effective cold chain network at these places is need of the hour. Diversification of the processed product base, including the production of low alcoholic fermented beverages to make use of surplus quantities of fruit, could be one of the several approaches to reduce the postharvest losses in the country. The quality and safety issues of fruit and vegetable products (freedom from microbial toxin & pesticide residues) is also need to be given greater attention in view of its significant implications for human health.

Based on the information given above the following efforts are needed to accelerate the pace of development of post-harvest infrastructure in the country.

1. Intensify the use of proper harvesting tools and gadget.
2. Popularize low cost sorting, grading equipment at farm level.
3. Popularize mobile sorting, grading, waxing and packaging concept on farm.
4. Develop marketing concept for minimally processed foods at production catchment.
5. Develop clusters of modern food factories in production catchment with good market links.
6. Develop facilities for hands on training in modern food factories.
7. Develop novel value added products from ethnic fruits & vegetable for niche market and export as health foods.
8. Encourage the corporate sector to undertake contract farming of crops to keep away multiple intermediaries between grower and processor.
9. Introduce private and corporate entrepreneurs in sharing investment in the establishment of efficient marketing systems.

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125-140

An Overview on Postharvest Sector in Jordan

Mohammad awaidah

Jordan

Introduction

Jordan has a very significant comparative advantage in the production and export of high value horticultural commodities during the off-season period, due to its location, unique climatic conditions, and proximity to traditional markets (Arab Gulf-States, Syria, Lebanon and Iraq) and EU eastern and western markets as compared to many other countries. Western Europe is the world's largest importing region for fresh fruit and vegetables, and Jordan initiated research to define market opportunities in Europe since 1991.

Jordan produces a wide range of horticultural crop almost year around. The Jordan valley which consider as a natural big green house make Jordan a good fresh fruit producer in winter season that could be exported to Europe. Jordan also produces horticultural crops in summer time at the high land areas to be exported to the Gulf-States where it's almost impossible to produce there under a very hot weather. Jordan is more than self-sufficient in most vegetables crops and self-sufficient in a few fruit crops.

Although Jordan have witnessed a tremendous change horizontally and vertically on fresh fruit and vegetables production during the last four decades, the post harvest sector has remained relatively unchanged, with high post harvest losses percentage, inefficient marketing systems, weak research and development capacity, and improper policies, infrastructure and information exchange. Such constraints within the post harvest sector have drawn the attention of the concerned agencies dealing with horticultural crops either from the public sector or from the private sector.

Post Harvest Losses

The range of post harvest losses in fruit and vegetables is estimated to be 5-20% in developed countries, and 20-50% in developed countries depending on the commodity. To reduce these losses percentages we must understand the biological and environmental factors involved in fruits deterioration, then use the post harvest technology procedures which will maintain quality and delay deterioration.

In Jordan, the post harvest sector is highly influenced by the marketing system. The marketing system of fresh horticultural crops suffers from different problems or constrains that limit the development of this sector. These problems and constrains affect either directly or indirectly the post harvest losses of horticultural commodities. Marketing problems and constrains can be divided in to subgroup in Jordan as follows:

Post harvest losses in Jordan are within the range of losses of many developing countries. Several studies had been conducted to estimate the losses for some important crops. The results revealed that the losses are high. The post harvest percentage losses were (19, 22, 23, and 18%) for tomatoes, squash, sweet pepper and eggplant, respectively. More investigation is required to determine the size of the problem in Jordan.

The post harvest losses causes in Jordan

1- Improper harvesting stage of maturity (immature, over ripe)

2- Improper postharvest handling practices in the marketing chain (field, wholesale markets, packing house of export firms, cold storages, transportation means, retailers and consumers).

3 - Improper packing (overfilling and over staking).

4- Improper package (poor material and design).

5- Absence of pre-cooling.

6 - Improper loading and unloading.

7- Absence of sorting any fruit not marketable from the field.

8- Water loss.

9- Poor temperature and relative humidity management.

10- Losses due to physiological, mechanical and pathological disorder.

11- Exposing the product to an appropriate conditions (light, temperature, relative humidity, rain, winds, ethylene).

12- In adequate transport means.

Infrastructures required for healthy marketing sector in Jordan

1- Efficient wholesale markets.

2- Packing house with grading machines

3- Efficient exporting firms.

4- Cold storages.

5- Apropraite ripening rooms.

6- Transportation means.

7- Pre-cooling units.

8- Package factories.

9- Marketing services

Export firms

There are two kinds of export firms in Jordan, depending on the targeted market. First kind is the export firms for the traditional markets (Arab Gulf-States, Syria, Lebanon and Iraq), and the second kind is the export firms to eastern and western Europe countries.

Traditional export firms

There are 40 export firms to the traditional markets.

All of them are owned by private sector

Export firms to Europe

There are 18 export firms to Europe .

Cold sorage fcilities

There are 60 cold storages facilities distributed in Jordan, with a storage capacity of 85000 ton.

Ripening rooms

There are 73 ripening room facilities,58 of them in Amman while the rest distributed in the cities of Jordan.

Transportation means

In Jordan, Mini-trucks, trucks, refrigerated trucks and airplanes are used to move fresh horticultural crops from shipping point to the destination markets. The major portion of exported crops is transported by refrigerated trucks mainly to the Arab Gulf-States, Syria, Lebanon, Iraq and Eastern Europe countries.

Pre-coling uits fcilities

Pre-cooling is removal of field heat from the fruits as soon as possible after harvest. This technology leads to a reduction in plant or plant part the following:

1- Respiration rate.
2-Water loss.
3-Ethylene production.
4-Pathogen infection.
5-Delaying ripening and senescence

In Jordan, the pre-cooling concept still limited for small-scale growers and unknown for many shippers (mainly shippers of traditional markets).

Packing and pckages fctories

Polystyrene. Plastic, carton and wooden boxes are used in Jordan for both local and export markets. Eight polystyrene factories located at different locations producing packages with several dimensions with a processing capacity to manufacture between 50,000 to 500,000 boxes a day. There are four factories producing more than 7 million of plastic boxes of different sizes annually. Four factories processing carton boxes. There are 20 manufacturing workshops for wooden boxes with different sizes and styles are operating in Jordan.

Vision for an active and an efficient marketing system for Jordan

1-An independent governmental umbrella involved only with marketing of fresh horticultural crops, and strongly co operate with private sector.

2-Qualified staff for both private and public sectors in the methods of production and marketing to insure high quality product.

3-Orientation the production in accordance with market demand.

4-Adequate infrastructure and marketing services.

5-Data base and market information intelligence.

6-Budjet financing agency for pre and postharvest technology required.

7-Strict and efficient legislations.

8-Anefficient exporting firms.

9-An active quality control system

10-Straight for wards training programs for growers on production (cultural practices) techniques and proper postharvest handling practices.

Post-harvest Losses of Tomatoes and Eggplants Produced for Local Market in Jordan

Introduction

Jordan produces a wide variety of horticultural crops around the year. Such an advantage is created by the combination of climate, soil, and topography of growing areas, namely the Jordan valley and the Uplands.

Tomato and eggplant are considered as fleshy fruit vegetables, although differ in their physiological characteristics from postharvest point of view. Tomato fruit, harvested mature, is a typical climacteric fruit, undergoes different metabolic changes associated with ripening in coordination with a climacteric rise in respiration, which marks the transition stage in the fruit development between maturation and senescence [2] . When harvested at the mature green stage, the fruit continues to develop and ripen similar to having been left on the plant [3, p 24]. On the other hand, eggplant, harvested immature, is a non-climacteric fruit that does not undergo the metabolic changes exhibited by tomatoes.

The objectives of this study were: to assess postharvest losses in tomatoes and eggplants grown in open fields in the Jordan Valley and the Uplands; to identify causes of these losses; and to propose means for reduction of postharvest losses.

Materials and Methods

Plant Materials: Tomato (Solanum lycopersicom L. cv. "GS12") and eggplant (Solanum melongena cv. "Black Beauty") fruits grown in the open field in the Jordan Valley (North and mid-valley) and in the Uplands (Al-Mafraq area) were subjected to this postharvest loss study. This study was carried out during October to July in the Jordan Valley (the minimum and maximum air temperatures were between 12.1 and 36.3℃), and during March to December in the Uplands (the minimum and maximum air temperatures were between 2.6 and 34.4℃) in 1999. Fruit samples of tomatoes and eggplants packed in polystyrene (Styrofoam) boxes (46 x 26 x 12 cm, holding 7-9 kg) were examined for postharvest losses at different levels (farm, transport, wholesale and retail markets) of the marketing chain. Fruits were handled traditionally as described below under postharvest practices for tomatoes and eggplants in Jordan.

Determination of postharvest losses: For each sample, ten boxes were taken at random at the study site. After weighing the contents of each box, unmarketable fruit (diseased, injured, immature green, very soft over mature, bruised, crushed, blemished etc.) were isolated, weighed (and returned into their box), and their percentage was calculated from the total weight of the box. The fact that postharvest losses are cumulative (i.e. increasing with the progression of postharvest handling) was taken into consideration in order to come up with the actual loss percentage at a given level. At the farm level, the percentage reported was the actual percentage of loss, since no preceding levels exist. Each of the reported percentages thereafter, was the result of subtracting the preceding percentage(s) from the newly obtained loss value for a given level. For example: the obtained loss at the transportation level was 11.6 – 6.0 (loss at the farm level) = 5.6 (actual loss at the transport level reported in Table 1).

Table 1. Percentages of postharvest losses of tomatoes and eggplants at four levels of postharvest handling in both growing areas

	Average loss %			
	Uplands		Jordan valley	
Postharvest handling	Eggplant	Tomato	Eggplant	Tomato
Farms	7.2	5.6	7.8	6.0
Transport	4.6	4.1	6.2	5.6
Wholesale market	1.8	1.1	2.1	1.5
Retail stores	5.4	6.3	1.9	2.7
Total loss	19.4	18.0	16.2	17.3

1. Represents the average of 90 boxes.
2. Means within the column followed by the same letter are not significantly different at $P<0.05$ levels by the LSD method.

Table 2. Color variation of harvested tomato fruit at the farm level.

Farm	Color stage1 (%)						
	G	B	T	P	LR	R	DR
J. V.[2]							
1st	4.3[3]	2.1	1.5	24.9	12.4	50.1	3.1
2nd	3.5	43.2	33.0	13.4	2.5	3.0	1.6
3rd	4.5	40.1	23.8	18.5	3.0	2.8	7.1
Up.[2]							
1st	2.1	40.1	28.1	21.1	1.4	3.2	3.3
2nd	3.7	4.1	2.8	10.4	27.1	41.7	1.7
3rd	3.2	2.9	5.1	21.4	18.8	45	3.9

1. G (green), B (breaker), T (turning), P (pink), LR (light red), R (red), DR (dark red).
2. J.V. (Jordan Valley) and Up. (Uplands).
3. Each value represents the average of 90 boxes.

Table 3. Decay and defect percentages of tomato fruit at the farm level.

Farm	Decay %			Defect %		
	Harvest frequency					
	3rd	2nd	1st	3rd	2nd	1st
J. V.[1]						
1st	3.6[3]	5.9	4.0	27.3	31.3	30.3
2nd	31.3	30.3	31.3	4.8	5.1	3.8
3rd	5.3	3.1	3.9	42.1	42.2	38.3
Up.[1]						
1st	30.3	27.3	23.8	6.3	4.3	5.0
2nd	6.4	5.2	6.0	41.0	37.8	48.8
3rd	3.3	4.3	3.1	33.8	42.3	41.8

1. J.V. (Jordan Valley) and Up. (Uplands).
2. Each value represents the average of 90 boxes

Table 4. Proportions of the different causes of postharvest losses of tomatoes and eggplants from the total loss at four levels of postharvest handling tested for both growing areas.

	Direct causes of postharvest loss (%)			
	Growing area	Diseases Disorder	Deffect	Mechanical damage
Jordan Valley				
Tomato	37.5	16.0	24.0	22.5
Eggplant	43.6	20.5	16.4	19.5
Uplands				
Tomato	27.3	22.3	17.4	33.0
Eggplant	39.8	16.5	22.1	21.6

1.Each value represents the average of 360 boxes.

Postharvest Losses of Tomato Fruits (*Lycopersicon esculentum* Mill.) and Grapes (*Vitis vinifera* L.) in Jordan, August 2000

Introduction

The environment and conditions exist in Jordan to produce large volume of high quality crops. All impedances to proper postharvest handling techniques are managerial and not physiological in nature due to lack of resources or infrastructure.

Generally, postharvest handling systems of tomatoes and grapes in Jordan can be summarized as follows:

*** Tomatoes for the local market:**

Harvest in buckets, wooden or Polystyrene boxes

▼

Sorting & Packing

▼

Loading & Transport

▼ ▼

◄Wholesale markets Exporters warehouse

▼

Repacking

▼

▼

*** Tomatoes for export to the Gulf States:**

Harvest in buckets, wooden or Polystyrene boxes

▼

Packing in Polystyrene boxes

▼

Loading & Transport

▼

Wholesale markets

▼

Retail Markets

Loading in refrigerated trucks

Shipping to destination markets

* Grapes Handling System

Harvest in field boxes ►Trimming and Primary Sorting► Packing ► Transport ►

►Cold Storage │►wholesale markets ► Retail Markets

│► Packing House ►Sorting, Grading & Re-packing ► Precooling │ ↓

►**Shipping to destination markets**

Objectives

The objective of the current study was to evaluate five common postharvest steps in the handling of tomatoes and grapes in order to estimate the postharvest losses and determine the causes of these losses.

Results and Discussion

1. Tomaotes

Color:

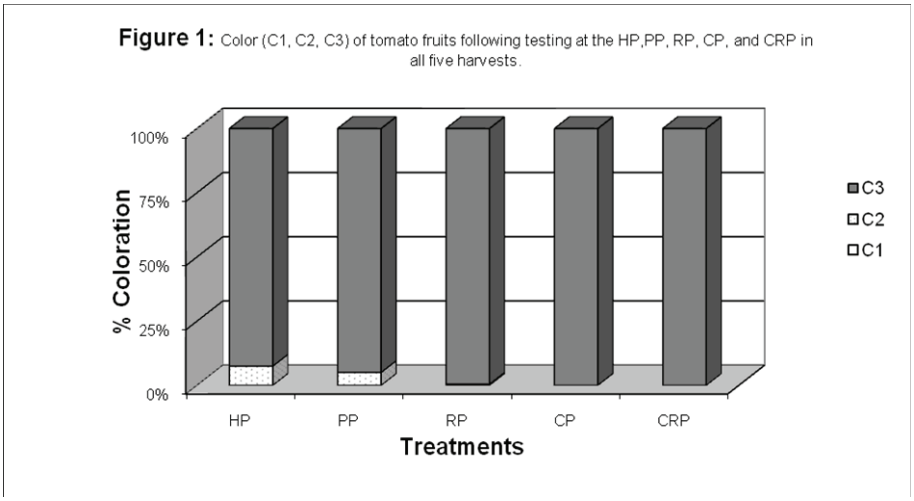

Figure 1: Color (C1, C2, C3) of tomato fruits following testing at the HP,PP, RP, CP, and CRP in all five harvests.

Firmness

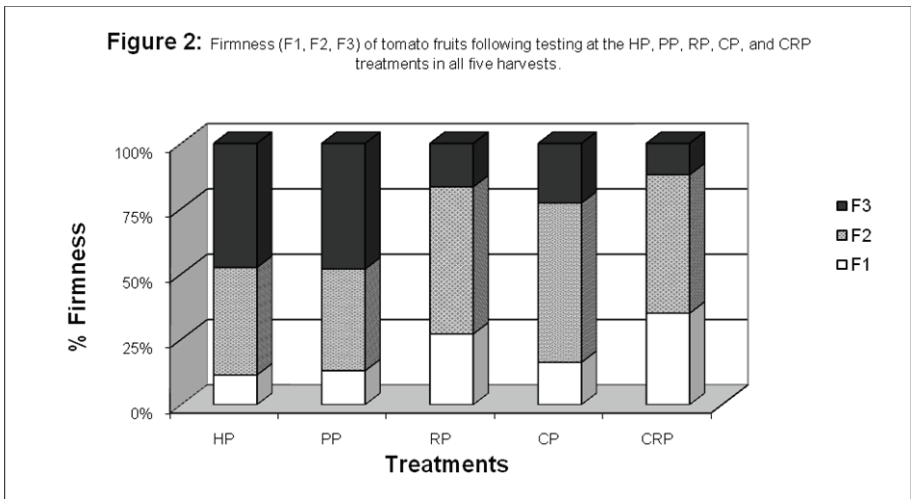

Figure 2: Firmness (F1, F2, F3) of tomato fruits following testing at the HP, PP, RP, CP, and CRP treatments in all five harvests.

Calyx Freshness

Table 3. Calyx Freshness 1,2 of tomato fruits following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP), in all five harvests.

Harv. ► **Treat.▼**	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
HP	85.87[3]a[4]	88.3a	72.0a	82.0a	76.3a
PP	83.66a	82.7a	76.3a	83.0a	81.7b
RP	47.0b	57.0b	50.7b	56.7b	34.0c
CP	61.3c	69.4c	63.0c	69.7c	66.3d
CRP	42.3b	30.6b	39.3d	37.0d	33.6c

1. Calyx freshness was rated as (1 = dry & brown), 2 = Partially green), and (3 = Green & fresh), the average of the three values was taken out of 3 which then were converted to percentages (3 considered as 100%).
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent fresher calyx.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Decay

Table 4. Decay1, 2 incidence in tomato fruits following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in all five harvests.

Harv. ► **Treat.▼**	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
HP	3.8[3]a[4]	3.8a	5.6a.b	3.6a	8.5a.b
PP	2.9a	3.8a	3.9a	4.7a	6.8a
RP	6.6a	9.3b	9.5b.c	11.0b	13.3b
CP	7.8a	10.8b	12.5c	10.2b	11a.b
CRP	29.1b	23.7c	28.9d	37.4c	26.0c

1. Decay was determined by the number of decayed fruits, converted to percentages from the total number of the fruits in each box (considered as 100%).
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more decayed fruits.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Defects

Table 5. Defects1, 2 occurrence in tomato fruits following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in all five harvests.

Harv. ► Treat.▼	1st H	2nd H	3rd H	4th H	5th H
HP	47.7[3]a[4]	61.7a.b	51.9a	53.2a	53.3a
PP	42.5a	51.5a	50.0a	59.5a.b	67.8a.b
RP	69.0b	69.4b.c	66.2b	67.8b	67.8b
CP	59.5b.c	62.3a.b	66.2b	62.9b.c	62.9b.c
CRP	72.5b	81.2c	85.9c	81.5c	80.5c

1. Defects were determined by the number of defected fruits, converted to percentages from the total number of the fruits in each box (considered as 100%).
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more defected fruits.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Cleanliness

Table 6. Cleanliness1, 2 of tomato fruits following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in all five harvests

Harv. ► Treat.▼	1st H	2nd H	3rd H	4th H	5th H
HP	71.3[3]a[4]	64.0a	67.3a	67.0a	63.6a
PP	72.0a	72.0a	71.0a	51.0a	65.3a
RP	56.7b	73.3a	72.0a	69.3a	71.7a
CP	72.0a	76.3	73.7a	71.7a	78.3b
CRP	69.7a	78.3a	73.7a	64.0a	66.4a

1. Cleanliness was determined using a scale of 1= dirty, 2= skin clean but calyx is dirty, and 3= completer clean.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more clean.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

General Appearance (GA)

Table 7. General Appearance1, 2 of tomato fruits following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvests.

Harv. ► **Treat.▼**	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
HP	76[3]a.b[4]	76.7a	77.0a	75.7a.c	72.7a.c
PP	81.0b	74.3a.b	79.0a	77.3a	76.0a
RP	73.3a.b	68.7b	73.0a	68.4b	68.3b.c
CP	69a.c	70.7a.b	72.0a	70.0c	69.3c
CRP	60.7c	61c	59.0b	55.7d	63.0b

1. General appearance was determined by 1= poor, 2= good, and 3= excellent.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent better general appearance.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

2. Grapes

Table 8. Total Soluble Solids (TSS) 1,2 of grapes following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvests.

Harv.► **Treat.▼**	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
HP	15.2[3]a[4]	15.7a	16.0a	16.3a	16.6a
PP	15.1a	15.5a	16.0a	16.8a	16.7a
RP	15.5a	16.2a	16.8a	16.9a	17.3a
CP	15.2a	15.8a	16.3a	16.5a	16.6a
CRP	15.5a	16.0a	16.2a	16.4a	16.6a

1. TSS was determined for each cluster by refractometer.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more TSS content.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Abscission (shattering)

Table 9. Abscission (Shattering) of grape berries1,2 following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvest.

Harv. ► **Treat.▼**	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
HP	10.83a4	10.2a	11.5a	15.3a.b	13.9a
PP	9.3a	9.7a	14.7a	11.7a	12.2a
RP	16.6b	15.2b	23.3b.c	15.2a.b	17.4a
CP	16.4b	12.8a.b	18.5a.b.c	17.6b.c	12.4a
CRP	18.4b	15.2b	25.8c	20.9c	16.9a

1. Shattering was determined by the number of missing berries from each cluster.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more shattering percentages.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Firmness

Table 10. Firmness1, 2 determination in grapes following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvests.

Harv. ► **Treat.▼**	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
HP	93.3[3]a[4]	96.0a	98.7a	96.0a	95.7a
PP	96.0b	96.3b	99.3b	97.7b	98.0b
RP	63.7c	61.3c	62.9c	55.0c	60.3c
CP	69.7d	76.7d	69.7d	65.d	68.6d
CRP	58.3e	49.7e	46.7e	51.7e	45.7e

1. Firmness was determined for each cluster using a scale of 1=soft, 2=firm, and 3= very firm.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent firmer berries.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Stem Freshness

Table 11. Stem Freshness1,2 of grapes following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvests.

Harv.► Treat.▼	1st H	2nd H	3rd H	4th H	5th H
HP	94[3]a[4]	97.0a	99.3a	98.3a	99.7a
PP	98.7b	93.3b	99.3a	98.3a	100b
RP	52.3c	47.0c	45.3b	38.9b	49.0c
CP	72.0d	77.4d	80.7c	73.0c	80.3d
CRP	50.3e	39.0e	39.0d	41.0d	42.0e

1. Stem freshness was determined for each cluster using a rating scale of 1= dry, 2= partially dry, and 3= fresh and green.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent better stem freshness.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Decay

Table 12. Decay incidence1, 2 in grapes following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvests.

Harv. ► Treat.▼	1st H	2nd H	3rd H	4th H	5th H
HP	2.0[3]a.b[4]	1.8a.b	1.5a	1.8a	1.4a
PP	1.3a	1.0a	1.9a	1.8a	1.5a.b
RP	3.0b.c	1.7a.b	2.6a	2.0a	2.8b
CP	3.3b.c	1.8a.b	2.8a	2.3a	2.0a.b
CRP	3.7c	2.2b	5.0b	3.8b	2.8b

1. Decay occurrence was determined by the number of decayed berries.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more decayed berries.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Defects

Table 13. Defect occurence1, 2 in grapes following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvests in the five harvests.

Harv. ►	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
Treat.▼					
HP	45.4[3]a[4]	34.4a	35.7a.b	39.7a.b	34.9a
PP	31.8a.b	20.3c	21.2b	21.2b	19.2b
RP	28.5b	30.4a.b	36.8a.b	36.8a.b	30.7a.b
CP	34.3a.b	23.2b.c	38.3a.b	38.3a.b	29.0a.b
CRP	37.4a.b	27a.b.c	45.6a	45.6a	38.4a

1. Defects were determined by the number of defected berries.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more defected fruits.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Cleanliness

Table 14. Cleanilness1,2 of grapes following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvests.

Harv. ►	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
Treat.▼					
HP	79.0[3]a.b[4]	84.7a	78.3b	82.0a.b	87.3a
PP	86.0a	81.7a.b	87.5a	85.3a	89.7a
RP	69.4c	69.4c	78.4b	71.2c	71.0b
CP	75.3b.c	79.0a.b.c	81.0a.b	74b.c	84.3a
CRP	68.3c	73.7b.c	62.3c	65.4c	59.2c

1. Cleanliness was determined using a scale of 1= dirty, 2= skin clean, but stem dirty, and 3= complete clean.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more clean clusters.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

General Appearance

Table 15. General Appearance1,2 of grapes following testing at the Harvest Point (HP), Packing Point (PP), Room temperature Point (RP), Cold storage Point (CP), and Cold storage + Room temperature Point (CRP) in the five harvests.

Harv. ► **Treat.▼**	**1st H**	**2nd H**	**3rd H**	**4th H**	**5th H**
HP	57[3]a[4]	70b	67a.b	68.7a	71.3a
PP	58.7a	77.3a	68.3a	71.7a	74.7a
RP	50a	54c	58.3b.c	51c	54.7b
CP	58.7a	68.7b	68.7a	59.3b	68.7a
CRP	53.7a	56.3c	52b.c	51c	49.3b

1. General appearance was determined using a scale of 1= poor, 2= good, and 3= excellent.
2. Means are the average of ten separate samples (10 boxes of fruits).
3. Higher values represent more fruits with better general appearance.
4. Values within columns followed by the same letter are not significantly different at the 0.05 level by the LSD method.

Postharvest Losses

Estimation of postharvest losses for tomatoes and grapes

Table 16. Estimated postharvest losses in tomatoes and grapes in the five treatments.

Treatment	% Losses in tomatoes		% Losses in grapes	
	The Assumed Lower Range	The Maximum Possible Range	The Assumed Lower Range	The Maximum Possible Range
HP	14.0	24.4	25.8	33.2
PP	13.1	22.5	23.4	29.1
RP	16.7	29.7	39.0	46.4
CP	15.7	29.8	29.3	35.2
CRP	25.0	40.2	40.3	47.5
Average loss	16.9	29.3	31.6	38.3

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Technology on Reducing Post Harvest Losses and Maintaining Quality of Fruits and Vegetables in Kenya

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Introduction

Horticultural sub-sector is the fastest growing industry in the agricultural sector in Kenya. It employs directly and indirectly about 4 million people. Small scale holder farmers contribute over 60% of the total production. The sub-sector generates over US$ 300 Million in foreign exchange earnings. Total horticultural production is close to 3 million tones, making Kenya one of the major producers and exporters of horticultural products in the world. The emerging issues such as maximum residue levels (MRLs) and social environmental accountability in the dynamic fresh produce markets and increased drought incidences makes it necessary for the industry to reposition itself so as to provide relevant, adequate, globally oriented products that are competitive and meet customer requirements.

Current Status of Fruits and Vegetables Practices

Crop loss through pests/diseases

1. Pests and diseases management has been a major challenge especially for small scale farmers.
2. Apart from being expensive, chemical control is not always effective against some of the major pests, including scales and mites and diseases such as anthracnose.
3. It has been estimated that approximately 35% of all crop is lost through attack by pests and diseases.

Post- harvest handling

1. Losses are common with agricultural produce marketing, even if nothing is actually thrown away.
2. Post harvest losses account for approximately 10% of the total horticulture produce. Poor harvesting techniques and poor on-farm handling (bruises, exposure to sun) damage the produce before they are sold to consumer.
3. Post harvest handling is as important as growing for delivering an attractive product to the consumer.

4. Harvesting of most fruits and vegetables is mainly done by hand before packaging. Fresh tomatoes for instance, are highly perishable, and unless proper post harvest handling procedures are followed, their quality declines rapidly due to bruises.

Lack of trainings/enforcement of regulations

The EU directives on traceability are currently of concern to Kenyan farmers and exporters of fresh produce to Europe. The regulations covers all food produced for consumption in the EU, both locally and imported. This poses major challenges, both financial and technical, to comply by many small scale farmers, hence leading to crop losses.

Tranportation

1. Poor off farm handling of fruits and vegetables causes considerable loss to produce. Delays in delivery of horticultural products to markets destinations have monumental costs in some products such as tomatoes-caused mainly by poor infrastructure (bad roads)and inefficient organizations.
2. Reliability of air connections is as critical as its costs.

Preservation /cold storage facilities

1. Cooling and storage facilities not available in most rural areas and even where they are available, farmers not adequately utilizing the facilities adequately owing to high storage costs/charges.
2. Facilities mainly utilized by large scale farmers and exporters.
3. Some horticultural crops such as tomatoes require forced air cooling to avoid excessive water loss, and provide high humidity cooling air.
4. Mechanical refrigeration also provides efficient systems for preservation of harvested products.
5. However, most rural areas where horticulture production is practiced have no electrical power, hence farmers not able to use these technologies.

Lack of organised markets/contract farming

Smallholder farmer are currently not well organized into production and marketing groups to take advantage of contract farming, thereby improving producer –buyer linkages and thereby reduce losses

Local utilization to products

1. The **Ministry** of Agric, promotes local utilization and consumption of horticultural products.
2. Utilization targets reduction of surplus production and or market rejects, and minimizes wastes.
3. This strategy reduces over-reliance on export market and encourages local consumption and value addition of horticultural products.

Processing/value addition

1. Processing is a common way of adding value to products.
2. Unfortunately, as farming becomes more commercial, such processing tends to be more in control of commercial firms, making it more difficult for small scale farmers to do such value addition for themselves.
3. A number of processors of horticultural crops are in operation in Kenya: - **Sunny Processors** in central Kenya and **Premier Foods** in the coast have established plants for Passion fruit processing.

Valley Orchard has a processing plant for passion, and **Del Monte** processing plant for pineapple and mangoes.

1. These investments in production and processing have the potential to make Kenya a market leader in tropical fruit juice.
2. Most small scale farmers, however do not benefit from the presence of the above processing plants because of low production volumes, and low quality.
3. Hence most of their raw materials are imported from Egypt and South Africa.

Technical and advisory services

1. Educating and continuous training horticultural growers on production, record keeping, harvesting and post harvest handling, especially for small holders being done.
2. Improving productivity through demonstrations on new technologies and introducing new crop varieties

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Post-Harvest Profile in Sultanate of Oman

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Abstract

To control the fruit and vegetables crops quality, knowledge and understanding of fruit and vegetables crops postharvest behavior and characteristics are necessary. Sultanate of Oman give considerable attention to the cultivation and development of fruit and vegetables crops. Ministry of Agriculture developing different research programs that aiming to improve productivity and quality of fruit and vegetable crops. The ministry of Agriculture also aimed to reach sustainable production of some important crops like date palm, banana and tomato. In addition, it contribute to the farmers by providing information knowledge of modern agriculture techniques and introducing high yielding varieties.

Introduction

The Sultanate of Oman occupies the southeastern part of the Arabian Peninsula and shares borders with the United Arab Emirates, Saudi Arabia, and the Republic of Yemen. It extends along the Gulf of Oman and the Arabian Sea. The country has a coastal line of almost 1,700 km, from the Strait of Hormuz in the north to the borders of the Republic of Yemen in the south-west, overlooking three seas: the Persian Gulf, the Gulf of Oman and the Arabian Sea. The Sultanate occupies about 309,500 sq. km equivalent to approximately 31 million hectares. The cultivable area has been estimated at 2.2 million ha, which is 7% of the total area of the country.

With the exception of Dhofar region, which has a strong monsoon climate and receives warm winds from the Indian Ocean, the climate of Oman is extremely hot and dry most of the year.

Summer begins in mid-April and lasts until October. The highest temperatures are registered in the interior, where readings of more than 53 °C (127.4 °F) in the shade are common. On the Al Batinah plain, summer temperatures seldom exceed 47 °C (116.6 °F), but, because of the low elevation, the humidity may be as high as 90 percent. The mean summer temperature in Muscat is 33 °C (91.4 °F), but the *gharbi* (literally, western), a strong wind that blows from the Rub al Khali desert , can raise temperatures from the towns on the Gulf of Oman by 6 °C (10.8 °F) to 10 °C (18 °F). Winter temperatures are mild and pleasant, ranging between 18 and 26 °C (64.4 and 78.8 °F).

Because the plateau of Al Jabal al Akhdar is porous limestone, rainfall seeps quickly through it, and the vegetation, which might be expected to be more lush, is meager. However, a huge

reservoir under the plateau provides springs for low-lying areas. In addition, an enormous wadi channels water to these valleys, making the area agriculturally productive in years of good rainfall.

Dhofar, benefiting from a southwest monsoon between June and September, receives heavier rainfall and has constantly running streams, which make the region Oman's most fertile area.

Agro-Climatic Conditions

Agro-climatic conditions in the Sultanate are classified as arid to extremely arid. Two main agro-climatic zones are recognized in the Sultanate based on the parameters which influence crop water requirements and efficient use of water, land and water resources potential and cropping patterns:

- Northern Oman including Batinah Coastal plain, Interior Oman and Dahira plains, Jebel Akhdar and Sharqiya plains.

- Southern Province, (Dhofar) including Salalah plain, Dhofar Jebel and Najd.

1. Production and Cultivation Areas

A wide range of crops are cultivated in the Sultanate. The permanent tree crops particularly Dates, lime and mango occupy the largest part of the cultivated land followed by fodder crops such as alfalfa and Rhodes grass, followed by vegetables and other seasonal crops (Table 1).

The cultivated area was 64314.7 ha in 2008, of which 28598.7 ha consisted of annual crops and 35716 ha consisted of permanent crops. Both fruit and vegetable production represent together almost 64.1% of the volume of total agricultural production in Oman. Over half the agricultural area is located in the Batinah Plain in the north, which has a total area representing about 3% of the area of the country (MA, 2008).

The aim of the Ministry is to achieve self-sufficiency in the main commodities of fruits, vegetables and field crops through the agricultural research strategy in crop pattern, which is based on selected crops to have the priority for research.

Table 1. Crop areas versus production in the Sultanate (MA, 2008).

Crop	Area (ha)	Area (%)	Production (Tons)	Production (%)
Fruits	35716.0	55.5	327625	28.3
Fodders	16276.0	25.3	662539	57.3
Vegetables	5732.0	8.91	141095	12.2
Field crops	6590.7	10.29	24567	2.2
Total	64314.7		1155826	

2. Priority of Crops.

Crop Priority is set according to the agricultural importance and agriculture policies. Agricultural importance takes in consideration the followings: the main region of production, total yield, yield per unit area, price/ton, net income/feddan, water use efficiency, imported and exported quantities of a crop or commodity.

The agricultural selected crop priority is as following:

Fruit: - Date palm, lime and other citrus species, mango, banana, coconut, papaya, grapes, deciduous crops in mountain areas.

Vegetables: Tomato, onion, garlic, potato, watermelon, cucumber, sweet melon, squash, carrots, hot pepper.

Field crops: Wheat, barley, maize and legumes.

Forages : Alfalfa and Rhodes grass.

3. Imported and Exported Products

The main distribution of fruit and vegetables in country is at Mawaleh market which located at Muscat capital where all fruits and vegetables from different region are marketed. Storage of all fruits and vegetables are in main storage place at Mawaleh markets and then are distributaed to different counties. While the export of fruit and vegetables of the regions are marketed to different counties for example UAE, Soudi Arabia, Kuwait, also some of fruits and vegetable are export to Europe and Japan. Import of fruits and vegetable are from different regions around the word for stance, Holland France, UAE, Soudi Arabia ect.

Quality Management Systems

Quality standards and specifications for some fresh products are available and updated frequently by the Directorate General for Specifications and Measurements (DGSM), Ministry of Commerce and Industry. There are 38 Omani specifications of fruits, vegetables and nuts available.

1. Current Status of the Post-Harvest Sector

General Overview of the Post-Harvest Chain

The available information suggests that more than 90% of Agricultural production in Oman is practiced on small farms, which are less than 4 ha (DAS, 2002). Thus producers are responsible for all activities related to growing, harvest, handling and marketing of their produces. However, there are relatively a very few number of specialized farms that have their own facilities in order to practice some sort of post-harvest techniques such as grading, treatment of fruits and packaging as requested by destined market.

Markets are mostly local or close by (less than 500 km), in which care is taken to determine the stage of ripening at which harvest takes place in order to minimize losses, which growers are aware of. Those losses, which might occur during and after harvest or those due to delay in marketing.

There are two central markets in the Capital (Muscat), which are mainly specialized for fresh fruits and vegetables. Grain and dry seeds are traded through local markets. This market receives all local and imported products.

Apart from farm initial grading, depending on the distance to markets, and packaging there are no other post-harvest techniques that are adopted. Packaging is normally done using carton or wooden boxes. Crates are also common for tubers and large leafy products. In some cases net bags are used.

2. Post-Harvest Units and Centers

Market and wholesale facilities are available in the Sultanate. As well as long-term cooled stores are available in certain areas particularly in the capital (Muscat). In addition, to the presence of few large scale commercial farms, which adopt post-harvest steps. There are some specialized centers for certain crops such as Dates and Banana.

Dates Handling in the Sultanate

Date palm trees numbers in the Sultanate is about 6,486,628. The total Dates production is about 219,771.80 tons and the average production of Dates per Date palm tree is about 33.9 kg (MA, 2008). The table 2 shows area cultivated under date palms indifferent regions of Oman.

Table 2. Date palm area cultivated in different regions in the Sultanate versus the production (MA, 2008).

Location	Date palm Numbers (%)	Production (%)
Al-Batinah	43.4	44.1
Al-Sharqiya	21.5	18.8
Oman Interior	14.7	18.0
Al-Dhahira	12.7	12.9
Muscat	5.2	4.6
Musandam	2.2	1.7
Dhofar	0.33	0.06

There are more than 200 cultivars of Date palm in the Sultanate but the commercial varieties are perhaps not more than 20 cultivars. The Omani cultivars are generally divided into three groups depending on time of fruit ripening. However, the difference is not distinct and is sometimes affected by climatic factors in various regions of the Sultanate.

Dates Pre and Post Handling

Dates take special attention by the Ministry of Agriculture , which has a strategy for Date palm development. The Ministry has launched an ambitious project in which, machines to process and pack Dates are distributed (subsidized by 50%) to farmers and small packers to establish small Date packing houses in an effort to introduce new techniques and ideas of the current pattern of consumption which requires modern attractive packages to fulfill consumers demands.

Private Companies Working in Dates Industry

There are about 8 companies investing in Dates in the Sultanate. These are:

- Tomoor Oman.
- Oman Modern Farm.
- Angara Trading.
- Billah Supply & Crops.
- Omani Dates Flake Factory.
- Muscat Overseas Agriculture.
- Muscat Food Industries.

Banana Handling in the Sultanate

Banana cultivated area in the Sultanate is 2642 ha (6.3% among fruits) and producing about 28,890 tons (10.3%) (MS, 2009). The most common cultivar is ‘Cavendish’ and have been studied and described for vegetative and bunch characteristics. Banana is highly developed and regulated through the strategy of the Ministry of Agriculture.

Banana Units

There are specialized Banana ripening and packing house in the Southern governate (Salalah) of the Sultanate and cold storage facilities in the central markets. In addition, to a receiving unit at Suwaiq on the Batinah Coast. Some farmers have initiated their own ripening rooms and chambers at their fields.

Banana Post-Harvest Practices

Bananas are a very high risk and demanding crop that requires constant attention to production, personnel and marketing management. Harvesting bananas is a big task and involves carrying heavy bunches, weighing more than 50 kg to the trailers. Particular care and training is

needed to avoid injuries to workers and damage to fruits.

Since, bananas deteriorate rapidly in hot sun, thus reducing their shelf life; farmers adopt the following steps to prevent this deterioration:

Pre-Harvest stage

- Plants are checked regularly and all rubbing leaves are removed or turned aside.
- The bunches are covered by plastic bags opened from both sides after complete development of the inflorescence (bagging) to prevent the fruits to be damaged by sunburn, spray residues, insects and birds.
- Incomplete hands are removed after bloom to increase the weight of the other hands.
- The bunches are not left ripened on the tree.

Harvest stage

- Bunches are harvested at light green stage.
- Banana is harvested with complete hands and when the fingers are fully developed.
- Bunches are collected in a shade area to be ready for packing.
- Padding is used to protect bunches during transport in the trailers or during storage.
- Washing.
- Banana are washed in water tanks and disinfected by using antifungal solutions in packing houses.
- Storing and Ripening.
- Farmers store banana bunches in well closed rooms at 15-19oC and relative humidity 85-95% for 24 hours in the first stage. Ethylene gas is used for ripening.
- Packing and Transport.

  Banana after ripening process are transported directly to the markets. Some refrigerated trucks are used to transport produce from collection centers to marketing outlets. Farmers also use their trailers to transport their commodity to the market but they use padding to prevent damages to the fruits.

Tomato Handling in the Sultanate.

Tomato is considered one of the main vegetables grown in the Sultanate. The area cultivated under tomatoes is 974 ha constituting about 14.3% from the total cultivated vegetables. The total tomato production is about 41925 tons (25.7% of total vegetable production).

Tomato Post-Harvest Practices

The bulk of the fresh market tomatoes are mature green stage because they tolerate rough handling better than the riper stages and hold the longest in storage, shipping, and on the supermarket shelf. In the industry, this is referred to as having a low shrinkage rate.

Steps of Tomato Harvesting

- Picking.

  Tomatoes are picked at 2 stages depending on the ripening. These stages are:

  1. Mature green: a white to yellow 'star' on the blossom end.
  2. Breaker, pink, and red: The breaker stage occurs within 24 hours of the mature green stage and is easily distinguished because the blossom end is pink.

  Farmers collect the fruits when completely developed or when it has reached the suitable degree of ripening. The fruits are picked without making any mechanical injury, while the damaged fruits are discarded.

- Sorting and Grading.

  The preliminary sorting take place at the field. The fruits with symptoms of infection of disease or infestation of insects as well as sun burn are discarded. As well as the up-normal fruits. This process is necessary to remove culled tomatoes and to separate the fruits into lots of uniform ripeness, consistency, size and appearance.

- Storing.

  Farmers traditionally don’t store tomatoes. They directly take the fruits to the market after harvest. However, some new advanced farms store tomatoes depending on the ripening stage.

  1. Green ripened tomatoes: Stored at temperature range between 12-14℃, which will reach the fully ripening stage after 20-25 days. Relative humidity at 85-95%.
  2. Partial ripened tomatoes: Stored at 10-12℃, which will reach the complete ripening after 15 days.
  3. Hard red tomatoes: Stored between 8-10℃ for one week.

- Packing.

  Tomatoes are packed in different sizes, materials, and shapes and then transported to markets.

Private Companies Working in Tomato Industry.

There are about 2 companies to our knowledge investing in tomatoes industry in the Sultanate. They are Ali and Abdul-Karim Company for food stuff and Al-Khabora. Both companies produce ketchups. However, most of their tomato concentrate were imported from outside the country.

Problems in the Post-harvest

Specific Problems

- Rough handling
- Inadequate cooling
- Temperature maintenance.
- Lack of sorting to eliminate defects before storage.
- Use of inadequate packaging materials.

General Problems

- Lack of specialized and advanced research in the post-harvest technologies.
- Shortage of Post-harvest facilities.
- Non-existence of educational courses at and at undergrounds level in universities.
- Lack of training to producers and workers on Post-harvest sectors technologies.
- Non awareness of consumers and public.
- Lack of private sector investment in post-harvest.

Conclusions and Recommendations

Conclusions

At present post-harvest technology in the Sultanate is mainly concerned with harvesting, collecting and preparing cereals, fruits and vegetables for trading, storing or processing. Post-harvest process is an integral function rather than separate entity. Therefore, efforts to preserve food should be adopted aiming in minimizing the factors that lead to deterioration by this integral function. These processes include drying, salting, sugaring, smoking, fermentation, even in refrigeration, packaging, freezing and storage. Prevention or decreasing post-harvest losses allows consumer to have access to more food product. The post-harvest activities are an integral part of the food production system. Most often post-harvest losses are considered symptoms rather than problems. Detection of the cause is therefore, essential for deciding measures to prevent that cause. Such measures may be taken by small farmers (producers), private traders, cooperative organizations, marketing procedures and handling and transportation undertakers.

Recommendations

- Improved markets. It can be either through private or cooperative, agricultural companies.
- Improved communications. Including feeder roads to make easy movement of produce possible
- Study the pre-harvest treatments to get good quality of fruits

- Studies to identify special standards mechanism of gathering or harvesting the fruits of different crops.
- Encourage farmers to use primary cooling for storage of agricultural products.
- The identification of crop species which will bring about the highest prices at home and abroad.
- Intensification of research for the protection of crops and the harvested produce from losses due to pests, diseases and weeds at pre and post-harvest stages.
- The preservation techniques of crops to maintain quality from the field to consumer, including package and storage.
- Development of proper infra-structures for most commodities such as cold storage facilities, packaging agencies and appropriate handling procedures.
- Identification of the correct stages of fruit harvest for each crop.
- Conducting training and educational programs to farmers and small producers.

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Technology Reducing Postharvest Losses and Maintaining Quality of Fruits and Vegetables (Philippines)

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Abstract

The Philippines is predominantly agriculture which covers 47% or 30 million hectares. However, the landholdings are small and non-contiguous. Fruits and vegetables grow well with the least inputs except when typhoons and drought hit the country. The bountiful harvest are wasted during the distribution process due to a number of reasons: use of inappropriate containers, poor road conditions, high temperatures, and rough handling. Postharvest losses could be up to 50%. While postharvest technologies are continuously being developed, transferred and adopted by the target sectors, the need for cooperation and coordination among the stakeholders is very critical. Information dissemination on the proper handling of fruits and vegetables through print and broadcast media must be sustained. Postharvest must be strengthened in the different schools as well as the extension manpower all over the country. The support for efficient postharvest facilities and infrastructures for perishable horticultural crops where the small producers would benefit should be prioritized. While the production areas are not increasing, the population is growing very rapidly. To ensure more food becoming available to consumers, a significant reduction in postharvest losses must be achieved.

Introduction

Fruits and vegetables play an important role in our nutrition as sources of vitamins, minerals, protein, and dietary fiber. The changing lifestyles and health conciousness of people is the driving force to demand for safe, quality, and organically grown fruits and vegetables.

The country is predominantly agriculture which covers 47% or 30 million hectares (Andales, 2000). Landholdings are small and non-contiguous. In general, farming is a family affair. Harvested produce are usually collected and combined by traders who transport and sell the produce to the wholesale and retail markets.

The country registered a 4.01 percent growth in Gross National Product (GNP) in 2009. Gross Domestic Product (GDP) expanded by 1.06 percent. Gross Value Added (GVA) in agriculture inched up by 0.03 percent and is 18% of the GDP in 2009. The country's total agricultural export earnings amounted to US$ 3,135.75 million in 2009. This was 19.37% lower than the 2008 record. Fresh banana is included as one of the top earners. On the other hand, agricultural import expenditures reached

US$ 6,079.80 million, 20.88% lower than 2008 (BAS,2010). The gross value of the crops subsector during first three months of 2010 grossed at 170.5 billion pesos.

The consumption of vegetables in the Philippines has remained low, 49 and 51 kg per capita in 1993 and 2003, respectively (Macabasco, 2008). However, changing patterns have been observed like increasing urban households, increasing purchases from supermarkets instead of the wet or traditional markets, and the availability of the fresh-cut fruits and vegetables in the markets. In a study funded by ACIAR in collaboration with UP Mindanao, the different institutional market segments for vegetables in Mindanao were identified: consumers are grouped according to their income. These include (1) the upper income consumers and foreign tourists; (2) upper income and some middle income consumers, budget tourists and conventional markets; (3) the wholesale consolidators which include the upscale institutional market, business market and wet market retailers; and (4) middle and lower income consumers. The lst group having the high income requires quality and food safety certificates. This group requires the widest range and sustainable supply of salad vegetables, temperate and tropical vegetables and herbs and spices. The 2nd group is more price conscious who requires mostly temperate and tropical vegetables. The 3rd group accounts for the largest volume of crops traded on wholesale market and has multiple sources of commodities. They have the capacity to import if their local supplier cannot deliver. The 4th group accounts for 75-80% of retail sales of fresh vegetables in the country. This group consumes mostly tropical fruits and vegetables and their quality requirement is not very strict (Concepcion, 2010).

The Philippines

The Philippines is in Southeastern Asia (longitude: 122°00 E and latitude: 13°00 N) and surrounded by the Philippine Sea, South China Sea and east of Vietnam. The northernmost group of islands in the Philippines is Batanes which is only 190 kilometers from Taiwan, while the southernmost island of Tawi-Tawi, is a mere 60 kilometers away from Borneo (Figure 1).

It is an archipelago with more than 7,100 islands. There are 3 main islands: Luzon, Visayas and Mindanao. Luzon and Visayas are frequented with typhoons while Mindanao is minimally affected. It has a total land area of 298,170 sq km with an estimated population of 97.9 million in 2009.

The country has a tropical rainfall climate characterized by high temperature and high relative atmospheric humidity. It has 2 seasons, the wet and dry. Another peculiarity of the country is the presence of typhoons with a yearly average of 20. Rainfall is from June to November. Lower temperatures (ave 20^{o}C) are during December to February.

It is endowed with fertile soils and tropical climate making it suitable for vegetable and fruit production. Varied horticultural crops are grown but only a few fruits are leading export winners (banana, mango, pineapple, papaya and citrus) to other countries like Japan, Korea, Singapore, Republic of China, and Hong Kong (Serrano, 2006). The vegetables which are considered high value include bitter gourd, asparagus, broccoli, cabbage, carrots, eggplant, garlic, ginger, gourd, habitchuelas,

lettuce, okra, onion, Chinese pechay, native pechay, stringbeans, tomato and white potato (Espino, 2010).

1. The fruit and vegetable industry situation in the Philippines

The production-postproduction-marketing system in the country is disjointed mainly due to the country's archipelagic nature. Huge losses and high costs are incurred because of the inherent nature of these horticultural produce, the tropical setting, lack of postharvest infrastructures and facilities, the way of handling and the multi-layered distribution system. The pattern of postharvest losses varies widely depending on the commodity, the distance of the source to the market, and the handling system practiced in the locality.

Figure 1. Map of the Philippines.

The Philippines, aside from being tropical is also the typhoon path in the Pacific. Challenges beset us not only the presence of natural calamities and its changing patterns (like the typhoon Ondoy in September 2009 which brought about 500 mm or 24 inches of rain water in 24 hours) but also of technical and non technical factors from production, post production and marketing of fresh horticultural crops.

The country is basically agriculture, majority are small producers whose landholdings range from 0.5 to 1 hectare. It is a hand-me-down activity for most producers with the tradition to grow what was grown by one's kins. The small producers need to be organized to have an efficient marketing and distribution system (Nuevo and Lizada, 1999).

Table 1 shows the production (metric tons, mt) of selected fruits and vegetables in the Philippines from 2007 – 2009. Banana (9,013,186 mt) topped the list followed by pineapple (2,198,497 mt) in fruits and eggplant (21,170 mt) production was highest followed by tomato (17,656 mt) in vegetables for the period of 3 years. In terms of area (hectares, ha) planted, banana (446,371 ha) consistently covered the largest area planted followed by mango (188.139 ha) (Table 2).

Table 3 shows the range of percentage of postharvest losses of different fruits (banana, calamansi, mango, and papaya) and vegetables (carrot, cabbage, eggplant, onion, and tomato), the causes of losses and the technology to minimize them. Postharvest losses are generally due to diseases, over ripening, mechanical damage and weight loss. These could occur during harvesting, and all along the handling route up to the consumers' level. In most cases, use of inappropriate packaging materials result in losses. This is aggravated by high transit temperature, rough roads and delays in distribution. Technologies to prevent losses are discussed in section IV.

Table 1. Production in (metric tons) of selected fruits and vegetables in the Philippines from 2007-2009. (Sources: Crop situations in the Philippines. BAS. 2003-2008; & Performance of Philippine Agriculture (Jan-June, 2010).

Commodity	2007	2008	2009
Banana	7,484,073	8,687,624	9,013,186
Calamansi	201, 619	199,675	192,187
Mango	1,023.907	884.011	771,441
Papaya	164.234	182,907	176,656
Pineapple	2,016.462	2,209,336	2,198,497
Cabbage	123,443	128,865	124,712
Eggplant	210,156	199,579	200,942
Onion	146,108	129.923	127.055
Tomato	65,024	68,366	198,948
Carrots	65,024	68,366	68,328

2. Production

Highland vegetables are grown on the terraces of mountain slopes of about 2,000 m above sea level. The heavy load of the produce are manually hauled from the farm to the roads via the rugged and steep terrains of the area. In some areas, the commodities are brought to the roadsides via animal -driven sleds. Another hauling style is securing two (2) baskets or sacks on the hind side of animals of horses or carabao. The produce are piled on the roadsides where traders could pick them up. Hauling containers are quite rough, oversized and mechanical damage easily set in.

Most fruits and vegetables grown by farmers are seasonal and highly dependent on rainfall. Lowland vegetable crops are usually planted after the rice season. Bagging is done in selected crops. Bitter gourds, mango and bananas are bagged. This protects them from insects and wind damage during its growth and development.

In some situations, the farmer cultivates and tends the vegetables with financing from a trader. The seeds and other inputs are provided by the trader and the harvested crops are delivered to the trader's wholesale market. On the other hand, immature fruits still on the tree are already bought while the trader keep watch over it until harvest and distribution to the market.

Table 2. Area planted (hectares) to selected fruits and vegetables in the Philippines from 2007-2009 (Sources: BAS, 2010 Commodity, 2007, 2008, 2009)

Commodity	2007	2008	2009
Banana	436,762	438,593	446,371
Calamansi	20,545	20,956	20,912
Mango	184,173	186,770	188,139
Papaya	9,125	9,175	8,904
pineapple	53,978	58,251	58,823
Cabbage	3,502	8,596	8,483
Eggplant	21,613	21,299	21,170
Onion	15,879	14,579	14,526
Tomato	17,544	17,646	17,656
Carrots	4,898	5,075	5,080

Table 3. Crops with percent losses, causes of losses, and technologies to minimize losses (Loss Assessment Report, 2009; Serrano, 2006).

Crop	% Loss	Cause of loss	Technology
Banana	3-30%	advanced ripening, weight loss, mechanical damage, disease and rotting	use of ethylene adsorbents, careful handling
Calamansi	5-32%	disease, oleocellosis, yellowing	curing, MAP (modified atm packaging)
Mango	2-33%	fruit drop cracking, disease, immaturity	HWT (hot water treatment), careful handling
Papaya	27-44%	disease, mechanical damage	wrapping of fruits, HWT (49–51℃ for 10 minutes)
Carrot	7- 12 %	crack/cut, soft rot/rot diseased, punctures, abrasion, cuts, forking, diseased, damaged top/leaves	use of plastic crates as packaging material; surface drying or air-drying of carrots after washing; use of refrigerated trucks for transport
Cabbage	29%	disease, mechanical damage	use of refrigerated truck; careful handling; passive cooling using block ice or evaporative coolers
Eggplant	10-40%	insect damage, shrivelling	careful handling
Tomato	11-38%	rotting, disease, weight loss	Use of MAP and ethylene adsorbents; careful handling; use of plastic crates
Onion	20-50%	disease, mechanical damage	curing; careful handling; use of cold ctorage

There are a few functioning agricultural cooperatives able to market their produce to Metro Manila and Metro Cebu. Leaders of these cooperatives try their best so the farmer members follow good agricultural practices (GAP) to be able to produce quality fruits and vegetables. The Department of Agriculture and the local government facilitate training of farmer leaders on GAP.

A shift to commercial enterprise in horticulture is now underway. A proliferation of protected farms for vegetables is increasing. The produce are distributed in high end markets like hotels, restaurants, fast food chains, and supermarkets. Leisure farms or agro-farms where vegetables are grown especially for city dwellers are becoming popular. Vegetable gardens are provided where people could plant or just harvest what they want to buy. Professionals who have retired from their 8 to 5 jobs have already ventured into agriculture of high value fruits and vegetables.

3. Postproduction

Handling practices start with *harvesting*; it may vary depending on the location. Simple harvesting tools are sometimes used but manual pulling is common in vegetables. Fruits like mango

from century old trees are harvested using picking pole. The fruits are not allowed to drop on the ground otherwise, these are rejected. Harvesting of banana is done by the ‘cutter’ who cuts the trunk and a ‘backer’ who carries the bunch on a pad on his back.

Harvested crops are usually placed in bamboo baskets or plastic sacks which do not protect the produce against mechanical injury. However, the use of plastic crates is now picking up. The harvested produce are *hauled* manually or placed on the hind sides of animals to the preparation area where the produce are sorted as good or rejects. There are noquality and size standards being strictly followed. During *sorting*, commodities are just placed on the ground with or without liners. However, some farms have packing areas with tables and benches where the produce are sorted. *Trimming* is another postharvest operation which adds value to carrots, calamansi, mango, onion bulbs. *Cleaning or washing* is done but not to all harvested produce. For commodities that need to be cleaned or washed, one issue is the frequency of changing the water especially if water is limited in the area. After cleaning, the produce are *packed* in wooden crates, bamboo baskets, polyethylene bags, plastic sacks and in some cases, plastic crates. Packaging materials used depend where the commodity originated. For example, bananas, from the southern part of the country particularly from Davao, are packed in wooden crates lined with banana bracts. This evolved because of the presence of the multi nationals into banana export. However, bananas from Agusan, a province also in Mindanao, are bulk loaded in 10-footer vans and loaded in ships. Bulk loaded bananas are provided with a wooden vertical divider, the original purpose of which is to delineate the produce of the different farmers in one van. However, the vertical divider aided in the dissipation of heat inside the van which is beneficia to the banana fruits.

Commodities are usually *transported* by ship from the southern part where crops are produced and marketed to the northern part where the major domestic market is situated. If there are no delays due to bad weather or technical ship problems, the transit time is about 36 hours. Delay in transport would lead to additonal handling cost, loss of volume and loss of potential profit (Bautista and Maunahan, 2007). When commodities in the metal van are loaded in passenger ships, the vans are placed below the boat where the engine is located. The temperature rises really high due to the engine heat and the heat of the commodities emitted in the process of respiration. Commodities are also shipped using cargo vessels which takes a shorter period of time (24 hrs). However, cargo vessels are more limited than passenger ships.

After the ship has docked, it will still take about 5-6 hours for the fruit van to be released. If fruits are bulk loaded, stripping takes another 16 hours. The bananas will then be transferred in trucks or oversized jeepneys and transported over land. However, the vehicle is always fully loaded and the handlers sit on top of the produce. The people sitting on the bulk loaded fruits add weight especially to the bottom fruits which results in compression damage.

4. Market

The supply chain of the produce is a multi layered system in the country. From the farm, fruits and vegetables are bought by (1) wholesalers from the urban wet market, (2) traders and consolidators, and (3) the processors. From the wholesalers, the produce are sold in the retail wet markets which will be bought by the consumers for their household. The wholesaler, trader, consolidators and processors supply the supermarkets, fast food chains hotels and restaurants. Consumers buy from retailers, supermarkets, and fast food chains (Figure 2).

Harvested crops are transported to the wholesale or retail markets in various kinds of vehicles. Trucks and jeepneys are used for long distance and a “tricycle” (motorcycle with side car) is used for short distancemarket. oading and unloading processes are still manually done where two to 4 bags of produce are carried at the back of the market handlers. In this manner, dropping of the packages is a common sight causing mechanical damage to the commodities. At the retail level, traders re-sort, rearrange, and repack into smaller lots of 5-10 kgs. n all of the traditional or wet markets, vegetables and fruits are displayed at ambient temperature, which is relatively hot (about 30℃). Thus, most fruits and vegetables could only be visually appealing for a day or two. However, in upermarkets where display shelves have temperatures ranging from 10 to 15℃ fruits and vegetables stay fresh for another 3-5 days.

At resent, the distribution system is quite inefficient ue to lack of functional ostharvest facilities, trading centers and packing houses, storage facilities for fresh, poor infrastructure and eak implementation of policies for agriculture. Lately, the government is establishing “Barangay Food Terminals” or village –level food terminals equipped with cold storage equipment for the storage of excess agricultural produce.

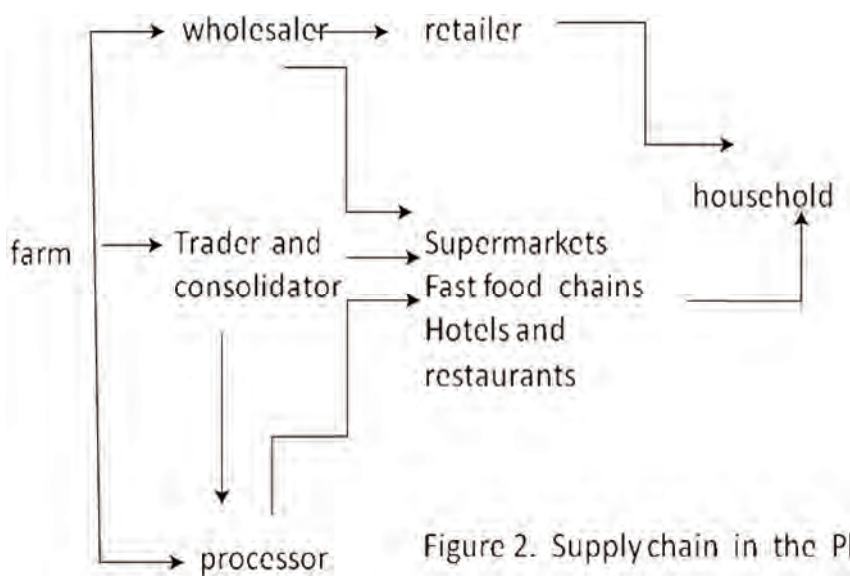

Figure 2. Supply chain in the Philippines

Postharvest Technologies on Rducing Pstharvest Lsses and Mintaining Qality of Fuits and Vgetables

The magnitude of losses could be traced during the pre- and postharvest chain of activities. Through the years, the following postharvest technologies have been developed and adopted by the industry.

1. Pre-harvest (Bagging of 'Cuarenta Dias' Banana)

This 'Cuarenta Dias' banana is grown by small farmers in the Cavite province and sold in bunches to local tourists. Bagging with polyethylene plastic bags as soon as the hands have emerged reduces the occurrence of unsightly scars caused by scarring weevil. Bagging also reduces wind scarring. The plastic wrap when not removed during transit serves also as protection to reduce bruises and latex stain. However, during summer months when temperature is high, bunches must first be wrapped with newsprint before covering with the polyethylene bag to prevent scalding.

2. Hauling (Tramline for mountainous areas)

Huge volume of vegetables especially the semi-temperate vegetables are grown in upland areas that are generally isolated from road networks because of ravines, rivers and dense vegetation. Hauling is generally done manually, or assisted by horses. The slow and long time needed to haul the produce to the nearest road usually result in higher postharvest losses due to bruising. Delayed hauling are experienced during peak harvest period due to lack of labor.

In minimizing the drudgery of manual hauling, the use of tramline system is being promoted by the government. The agricultural tramline system provides fast and reliable means of transportation for the harvested agricultural products and agricultural inputs to and from the mountainous production area to the nearest accessible road thus, reducing the hauling time and cost. It is a hauling facility using cables and pulleys to transport agricultural produce and inputs.

3. Maturity Determination (Flotation Method)

Harvesting the Philippine Carabao mango at the immature stage does not quarantee normal ripening and full aroma and flavor. It is also very susceptible to internal breakdown during high temperatures. A non destructive method of evaluating fruit maturity is dipping the harvested fruits in 1% salt solution. Mature fruits sink due to higher specific gravity while the immature ones float and easily sorted out. This method could be done in the farm as soon as harvesting is over.

4. Disease control (use of alum, hot water treatment [HWT] optimization)

Cabbage grown from the highlands is very susceptible to bacterial soft rot especially during the wet season and temperature is high. The use of alum proved to be very effective in preventing this.

Alum dissolved in warm water is applied by brushing, wiping or spraying to the trimmed butts. It penetrates host tissues and prevents the development of the disease even if the bacteria have set in.

In mango, anthracnose and stem end rot are the common postharvest diseases that cause significant losses. Symptoms appear when the fruit ripens. One effective way of controlling this is the use of hot water treatment at 52-55^{o}C for 10 minutes. In papaya, a lower dipping temperature was optimized. Through time, HWT tanks for disease control are now fabricated for commercial use.

5. Delay Ripening (MAP, wax emulsion for 'Queen' pineapple, ethylene adsorbent,)

MA packaging is an alternative method in extending postharvest life of some commodities (calamansi, tomato, banana). When the produce are placed inside the polyethylene bags, the respiration process slows down due to carbon dioxide accumulation and gradual reduction in the oxygen level. The other benefits include reduced moisture loss, delayed ripening, alleviation of chilling injury and increased shelf life.

Another kind of modified atmosphere in fruits and vegetables is the use of wax emulsion. The technology involves the application of a locally formulated wax emulsion on the fruit surface. This modifies internal fruit gases and subsequent reduction in respiration, extension of shelf life and external quality.

The development of ethylene adsorbent from indigenous waste materials was done as an alternative to imported ethylene adsorbents. Ethylene is a ripening hormone emitted by all commodities that stimulates ripening and deterioration. The role of the adsorbent is to remove the ethylene from the atmosphere surrounding the commodity, thereby retarding senescence and extending shelf life. This is effective when the commodities are in an enclosed condition. This has been done in bulk loaded bananas from Mindanao to Metro Manila.

6. Storage (low cost drip cooler for short term storage of vegetables, use of coconut coir dust)

A drip cooler made of wooden framing and walls made from an absorbing jute sack was fabricated. Evaporative cooling utilizes the cooling effect brought about by the evaporation of water from a wetted surface. The high humidity maintained inside the cooler minimizes moisture loss from the commodity. This technology was used for temporary storage of sweet corn before delivery to the supermarkets.

The use of moist coconut coir dust which is abundant in the country was adopted by farmers especially during peak periods and low market prices of tomato. Green mature and disease-free tomatoes buried in moist saw dust can be extended as long as 3 weeks, with minimal weight loss and full red color development.

7. Transport/Logistics

Generally, fruits and vegetables are transported using open/dry transport system. Transport capacities depends on the volume of produce to be transported and distance of travel ranging from small vehicles such as 'Jeepneys' to 10-wheeler trucks and container vans ranging from 10-footer to 20-footer container vans. Inter-island transport is facilitated using roll-on roll- off system. The produce are usually packed using polyethylene bags (PEB), bamboo or wooden crates piled on top of each other inside the vehicles or vans. Huge losses are observed during transport due to moisture loss, accelerated ripening, and other physical damage like bruising, abrasion and compression.

To address the huge losses during transport, the government introduced the cold chain system in the handling and transport of high value fruits and vegetables. The Cold Chain System is a series of inter-connected handling operations of horticultural produce from the farm to the market with focus on the maintenance of environmental conditions of the the appropriate temperature and humidity at very point (Fig. 3). The chain starts from the farm and ends at the retail market. The components include packinghouse, pre-coolers, refrigerated transport, cold storage and refrigerated product display facilities at the retail market. The use of clean plastic crates is critical under the cold chain system.

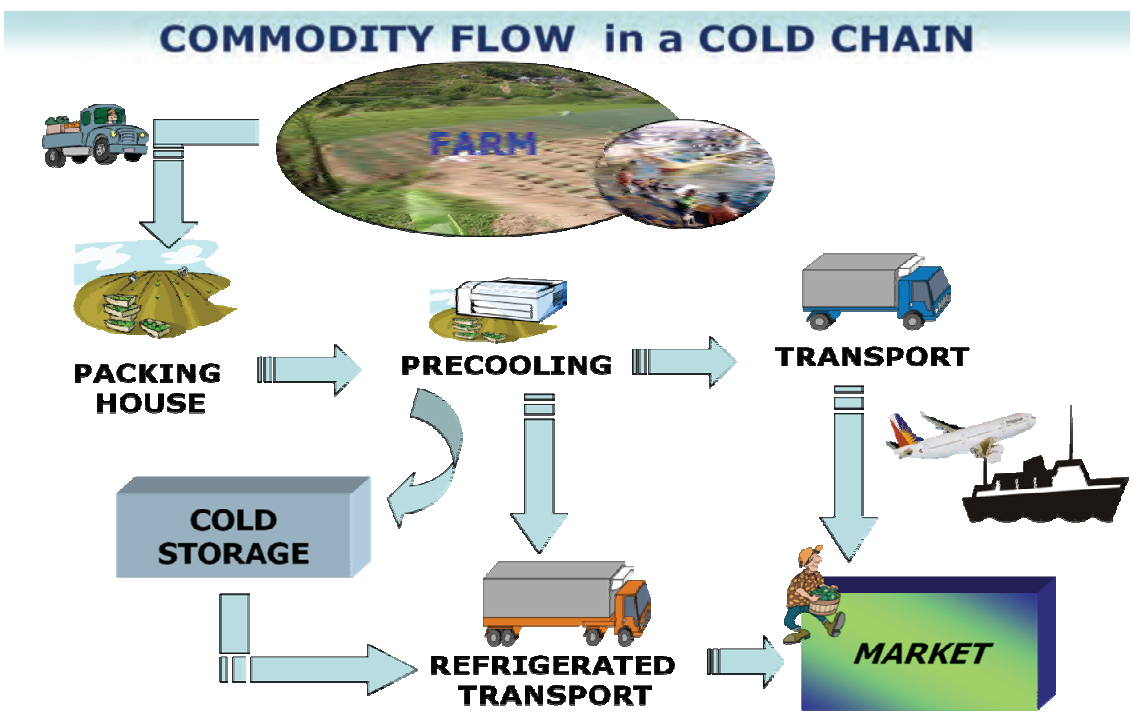

Figure 3. Commodity flow in a cold chain diagram.

Role of academe

Very few schools in the Philippines are teaching postharvest science courses. Compared with the other fields of study in the university, postharvest is a relatively new. Of the more than 200 agricultural schools and colleges of agriculture, less than 10% teach Postharvest Handling of Horticultural Crops as a subject (Bautista and Maunahan, 2007). While the postharvest unit of the university work in coordination with the local government units and the department of agriculture, there are still a lot of researches to be done. However, one drawback is the support for postharvest basic research.

Currently, the university offers postharvest as a major course in the Agriculture curriculum. Aside from the regular semester for agriculture students, a summer short course on postharvest handling is conducted. Attendees to this training include, government and non-government agricultural extension staff, people from the industry like supermarkets, exporters, and entrepreneurs. Invitations and arrangements are also done for the postharvest staff to go to the area and conduct postharvest awareness training workshops in the provinces. Information materials on the proper handling of horticultural crops are also developed and updated.

Role of government and policy makers

Way back in 1998, the Philippine government enacted the Republic Act 8435 Law, also known as the Agriculture and Fiisheries Modernization Act (AFMA) which provided the master plan for development and modernization of agriculture. The AFMA states that agriculture be modern, science and technology-based, more integrated in the national and international markets thus more efficient in terms of productivity. Provided in the AFMA are provisions to reducer postharvest losses in agricultural commodities through:

- Establishment and modernization of postharvest, transport/logistic facilties to ensure efficient flow of commodities, maintain quality and reduce food losses;
- Capacity and capability strengthening and enchancement of agencies such as the Bureau of Postharvest Research and Extension(BPRE) now Philippine Center for Postharvest Development and Mechanization (PHilMech), of the Department of Agriculture and academic institutions such as the Postharvest Horticulture Training and Researchg Center (PHTRC) of the University of the Philippines Los Banos, mandated to address RDE postharvest – related concerns.;
- Establishment of the Bureau of Agriculture and Fisheries Product Standards (BAFPS) to facilitate in the formulation of grade standards and enccourage quality consciousness that would meet both domestic and foreign market requirements; and
- Establishment of a National Marketing Assistance Program (NMAP) that will support marketing and postharvest commerce of agriucltural products.

Conclusion

Production of vegetables and fruits in the country is affected by geographic factors, climate and soil. Crops grow well with the least inputs except when typhoons and drought hit the country. The bountiful harvest are wasted during the distribution process due to the use of inappropriate containers, poor road conditions, rough handling and high temperatures. While postharvest technologies are continuously being developed and adopted, the need for cooperation and coordination among the stakeholders is very critical. There are so many constraints to overcome not only the by farmers but also the traders, service providers, and the market. Information dissemination on the proper handling of fruits and vegetables through print and broadcast media must be sustained. Postharvest must be strengthened in the different schools as well as the extension manpower all over the country. The support for efficient postharvest facilities and infrastructures for perishable horticultural crops where the small producers could benefit must be prioritized.

Quality management systems for horticultual crops like Good Agricultural Practices (GAP), Hazard Analysis and Critical Controls Points (HACCP) and the ISO 9000 series are investments to be able to achieve the our goals and deliver quality produce and services. While the production areas are not increasing, the population is growing very rapidly. To ensure more food becoming available to consumers, a significant reduction in postharvest losses must be achieved.

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Status Report on Fruits and Vegetables Production and Processing Industry in Sudan

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Abstract

Sudan has a great potential to produce good quality fruits and vegetables. This is because of its large areas of fertile soil, abundant amount of water from rivers, rains and underground water, suitable wide range of climate which allow variability of crops. Studies showed high losses (30→40%) of fruits and vegetables during harvesting, transport and handling. These losses add to the cost of production and have negative impact on marketing and hence national economy. Therefore adoption of proper post-harvest techniques, investment in the infrastructure and post-harvest technology should be established.

Introduction

Sudan is one of the largest countries in Africa (250 million hectares), strategically located in the center of Africa making it a melting pot between Arabs and sub- Saharan peoples. The country shares extensive boarders with nine countries in the northern, central eastern and western Africa.

It lies within the latitudes 4-23 degrees north and longitudes 23-28 east. It has a wide climatic variation with several distinct ecological zones including high altitudes or mountainous regions in the west (Jabel Marra) and east (Red Sea Hills) that have Mediterranean climate.

Considerable water resources are available which include the White Nile, the Blue Nile and the River Nile and their tributaries, seasonal streams and rains with an annual amount of 109 billion m^3 of water in addition to the underground water i.e. the Nubian Sand-Stone Aquifer which is one of the largest water reservoirs in the world with an estimated rechargeable potential of 29 billion $m^3$of water (HS, 2003).

Sudan has 80 million hectares of fertile soil but only 20 million hectares are cultivated. Agriculture remains the leading sector in the Sudanese economy with an estimated contribution of 45% to the GDP. The agricultural sector provides employment for about two thirds of the industrial sector (CBOS, 2008).

1. Status of Fruits and Vegetables Production Compared to Total Agricultural Production

Many types and cultivars of fruits and vegetables can be produced almost all the year round due to the climatic variations plus available land and water. This large potential could supply both local and export markets. However, horticultural crops represent about 12% of the national agricultural income, compared to 17% for cotton and 29.6% for cereals and oil seeds. Hence the economic impact of fruits and vegetables is still very limited compared to their actual production potential in the country. This is due to less attention paid to them compared with the cash crops e.g. cotton, gum Arabic and the staple food grains. Even reliable data on the area and production of fruits and vegetables are still difficult to obtain.

Various vegetables are grown in both irrigated and rain–fed plots, in a total area of about 273,000 ha i.e. about 3% of the total cultivated area producing on average about 3.4 million tons of vegetables. The most important vegetables are onions and tomatoes followed by potatoes, okra, eggplant, water melons, cucumbers, pumpkins and a number of leafy vegetables. Vegetables are grown in small plots with pumped water including the national corporations such as Gezira Scheme where about 30,000 ha are devoted to vegetables. Table 1 shows area and production of some major vegetables during the period 2005 to 2009.

Fruit production in Sudan needs very little agro-chemicals thus the fruits are relatively free of chemical residues which if certified could give a comparative edge and a competitive advantage in international markets. The variations in climate and topography created conditions for the production of various types of fruits including date palms, citruses, mangoes, guava, pine apples and banana**.** In the high areas of Jabal Marra temperate fruits such as apples, grapes, strawberries and sweet oranges grow well. However, commercial production is hampered by the lack of investments and poor transportation facilities. The estimated total fruit production in Sudan is about 1.9 million tons in a cultivated area of about 186,000 ha. The area and production of some major fruits grown in Sudan during the period 2006-2009 are shown in Table 2.

Table 1. The area ('000 feddan) and production ('000 tons) of common cultivated vegetables crops in Sudan.

Year	**2005**		**2006**		**2007**		**2008**		**2009**	
Crop	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
Onion	110	688	113	900.8	115	920	117.3	938.4	128	1024
Tomato	66	396	68.3	409.8	72	432	76.3	453	80	480
Okra	42	210	45	220	48	235	48.4	249	48.9	252
Egg-plant	8.2	65.6	8.8	70.4	9	72	9.2	75.6	9.4	75.2
Potato	36	252	37.7	263.9	39	273	41	284	43	301
Cucurbits	72	504	78	546	81	567	84.2	589	88	616
Leafy -Vegetables	10.8	54	11	55	13	65	15	66.3	17.2	68.8
Sweet potato	16	112	17	119	19	133	21	147	32	216

One hectare = 2.38 feddan. (HS, 2009).

Table 2. The area ('000 feddans) and production ('000 tons) of the major fruits grow in Sudan.

Year	2006		2007		2008		2009	
Crop	Area	Product.	Area	Product.	Area	Product.	Area	Product.
Mango	67.8	611	68	632	68.2	651	68.5	616.5
Banana	43	516	45.2	540	47.2	561.6	52	624
Lime	30	210	32	224	34	233	36	236
Grape fruit	24.5	147	26	156	27.5	165	29	174
Orange	23	115	24	120	24.9	124.8	25	124
Dates	83	332	84	336	84.8	339.3	85.5	422
Guava	16.5	115.5	17	119	17.5	122.5	18	126

One hectare = 2.38 feddan. (HS, 2009).

Mango tree is the number one fruit tree in terms of production, followed by banana, date palm and lime. Sudan produces about 5.7% of the total Arab world production.

Mango is the main fruit produced in the northern states e.g. Western Darfur, Southern Kordofan, Northern and Khartoum states. Kassala State is the main area for banana production (*ca.* 35%), followed by Blue Nile (*ca.* 25%), Gezira, Sennar and Khartoum states. Grapefruit and oranges are mainly produced in the Northern State (*ca*. 60% & 40% respectively). Oranges are also produced in River Nile and Western Darfur states. Both dry (75%) and semi–soft (25%) dates are produced by small farmers in the Northern and River Nile states (PAB, 2003).

2. Major Constrains in Fruits and Vegetables production:

1. Lack of sufficient improved management technologies.
2. Inadequate financial and credits facilities.
3. Land fragmentation.
4. Poor vegetables seed production.
5. Limited application of agricultural research findings due to inadequate extension services.
6. Low productivity due to poor and traditional cultural practices.
7. High cost and improper local transportation.
8. Weeds, pests and diseases.

3. Main Distribution and Production of Fruits and Vegetables

Most of the horticultural production in Sudan is under irrigated farming system, along valleys and streams in the western states and the areas of high rainfall in the south. Most of southern Sudan and the fertile locations in South Kordofan, Southern Darfur, Southern Sennar and Blue Nile states are considered main potential areas for horticultural production (HS, 2009).

The most important vegetables are mentioned in Table 1. Other vegetables like carrot, cabbage,

red beet and cauliflower are grown at the outskirts of large cities. These vegetables are grown in different areas and marketed in the same or other areas. Vegetables acreage increased tremendously in the last few years due to the increased urbanization, awareness of their nutritive value and high returns per unit area. Both production and consumption of fresh vegetables and fruits are increasing due to relatively high demand locally and externally. The rate of consumption from fresh vegetables and fruits per annum is about 43 kg and 32 kg/person respectively (PFS, 2005). The increase in vegetable production is rather horizontal, productivity remains low and lags far behind international yields indicating high potential for improvement through better cultural practices, improved varieties and protection against pests and diseases. At present horticultural production is a flourishing enterprise in the country. The national strategy (2002-2027) emphasized the importance and role of the horticultural sector in development plans and on the national income (Abdelkareem, 2003).

4. Post-harvest Handling and Processing

Generally, huge losses occur in the horticultural crops due to poor post-harvest practices. Losses range between 30% - 40% (HS, 2003). These have a negative impact on the national economy.

5. Storage

Refrigeration of fruits and vegetables started in the early seventies (FRC, 1998) with the compelling need for potato storage. Later, many cold stores were established to about 10.000 tons capacity with extra storage in the Northern State.

Exhibition of fruits and vegetables at the local markets is very poor because the markets are not properly equipped for their exhibition. Numerous packing materials mainly for bulk packing are used that do not satisfy the consumer taste, for example:

- 15 kg tin packs for tomatoes.
- Different sizes of local containers made of palm trees leaves.
- Onions jute bags 50 kg.
- Potato jute bags 50 kg.
- Fertilizers sacks which are used for eggplant and okra.

All these containers are available at the local markets and are the main reason for post-harvest losses for retailers (FRC, 2008). These containers are against the requirements of ISO 9000 and Environment ISO 14000 (Elyas, 2008).

The horticultural crop supply chain

The chain involves:

Harvesting: Manual.

Handling and preparation: Cleaning, sorting and grading all carried out manually.

Packaging: Manual e.g. tomatoes packed in 4-gallons tins, mangoes and grapefruits in locally made baskets and imported jute sacks for dates/lime or oranges.

Transport: Most of the crops are transported by animals or lorries to local consumption villages or urban cities' central markets.

Marketing: The products are sold at road sides, village household stalls, urban cities street markets and some supermarkets. Some producers sell their products directly at different markets i.e. to an assemblers or itinerant wholesalers. No real markets exist in this case. The products are being transferred directly from the centre of supply to the centre of consumption.

The following practices are specific causes of post-harvest losses

(1)Banana

Bananas are grown in the Blue Nile and Kassala states about 600 km from Khartoum markets. They are transported in 5-6 tones trucks where banana bunches are stacked to the maximum permissible load. Most of the bruises which appear later after ripening are due to the harvest and transport methods. Post-harvest losses of bananas are about 35%.

Dwarf Cavendish is the predominant cultivar which in spite of its locally preferred taste and flavor, it has short fingers and is a poor keeper and shipper, a major reason for its unacceptability in the world markets. Fortunately, new banana cultivars have been released recently from the Sudan National Variety Release Committee targeting the export markets such as Granien and William.

(2)Mango, Guava and Citruses

Mango, guava and citruses (lemon, oranges, mandarin and grape fruits) are harvested mainly by using a hook and stick. This method increases losses during handling and storage due to the fall and contact with the ground that causes fruit deterioration. International cultivars of mangoes and grape fruits were recently introduced such as Kit, Kent, Tomyattkins, Sensasion and Haden for mangoes and Ray Robby, Rio ruby, Chamber, Froset march for grape fruits to secure the export market.

(3)Melon

Export of Gallia cultivar induced the producers to use improved methods of harvesting and packing but the main problems are time of harvest and packaging. Post-harvest losses of melons are about 15-20%.

(4)Dates

Dates are harvested manually by cutting the bunch and dropping it to the ground. causing losses of up to 50%.

(5)Leafy vegetables

Leafy vegetables like Jews mallow, garden rocket, dill, purslane and parsley are produced for the

local markets. These vegetables are packed in local straw containers and exhibited covered with jute sacks soaked in water. They are totally lost after 24 hours from harvest.

(6)Potatoes

Potatoes are harvested manually when the vines turn yellow. Tubers are cured for 10 days in the field in shallow pits called 'Boata' covered with potato vines. The tubers are then packed in jut sacks and placed in the same field under the direct sun rays (30-37°C) for 2-3 days waiting for loading to the cold store. This method leads to poor potato quality and about 30% losses.

6. Post-harvest Research

Research in the field of post-harvest technology is mainly conducted at the Post-harvest Physiology and Storage Department, Food Research Centre. It was established in 1969 to improve post-harvest techniques by minimizing the losses, improving the storability and maintaining the quality of the horticultural crops. A number of researches were carried out on the:

- Improvement of local harvesting methods (maturation and maturity indices, best local tools for harvest and suitable containers for harvest, handling and export).
- Preparation of fruits and vegetables for export (sorting, grading, waxing and packing).
- Ripening of climacteric fruits (banana, mango and guava).
- Degreening of citrus.
- Suitable storage temperatures for export fruits and vegetables.
- Improvement of local methods of onion storage.
- Introduction of cold storage techniques for fruits and vegetables such as, potato, mango and citrus.
- Publishing booklets on the standard metrology indices for Sudanese fresh fruits and vegetables for local market.
- Extension of shelf life of vegetables and fruits using gamma irradiation (potato, guava, mango, banana and onion).
- Evaluation of fruits and vegetables for processing and export markets.

Studies on post-harvest technology including canning (jams, tomato paste etc), drying (okra, potato) are conducted in the dehydration and canning sections, Food Research Center.

However, the research findings are poorly applied hence their low contribution to the national economy. This is due to inadequate extension services and limited investment in the food industry. Post-harvest technology research can contribute more to the national economy since Sudan can add to the world markets' supply of mango, grapefruit, lime, guava, pineapple and papaya whether fresh or concentrates.

7. Post-harvest Research Constraints

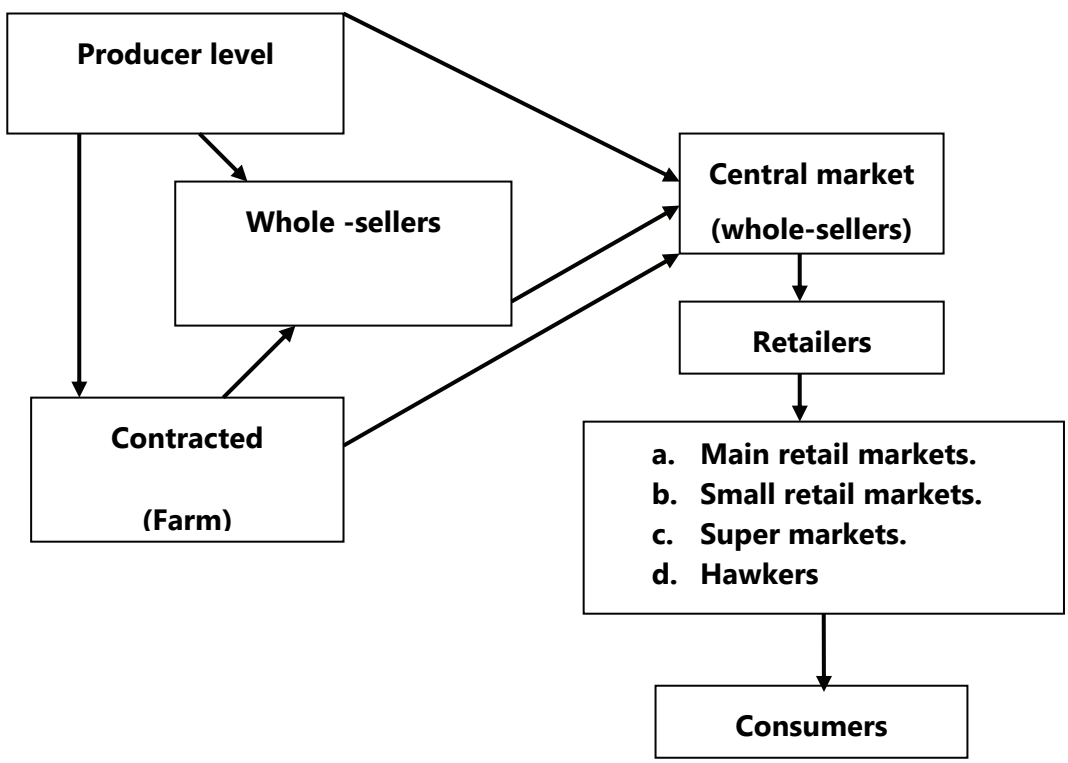
- Limited number of well trained technical staff.

- Weak linkage between research and the industrial sector.
- Limited training opportunities for research scientists and technical staff abroad.
- Weak linkage with the international information and research centers.

8. Fruits and Vegetables Markets

There are no marketing institutions dealing with fruits and vegetables. Farmers and producers deal as individuals directly with local traders and exporters. The trade lacks exhibition sheds, loading and unloading platforms, cold stores and trucks loading equipments. Therefore the producers sell their products early in the morning at very low prices especially perishable vegetables, i.e. tomatoes. The central markets are administrated by local authorities who collect fees for services (waste disposal) and rents for selling stalls and shops. Farmers and traders associations exist in Kassala, Gedarif, River Nile and Northern states.

The main local markets are in Khartoum, Khartoum North, Omdurman, Wad Madani and Port Sudan (Abdalazeez, 2005). The trends in domestic, regional and international markets are shown in the following diagram:



The performance of the horticultural crops marketing system is irregular in terms of prices, profits and cost of production and is unsustainable hence it is a traditional and ineffective system. Table 3

shows the cost of production of some horticultural crops in Kassala State.

Table 3. Average cost of production and financial profit margin for main vegetables and fruits in Kassala State.

Crops	Cost of production (SDG/ton)	Selling price (SDG/ton)		Profit (SDG/ton)	
		During season	Off season	During season	Off season
Onions	150	200	1200	50	1050
Tomatoes	500	1000	10000	500	9500
Mangoes	535	1162	4980	827	4645
Grapefruit	325	600	2000	275	1675

Source: Ministry of Agriculture, Kassala State (2003).

The selling price fluctuates greatly at the beginning of the season and during the season. For example, tomatoes will be sold at a low price at the start of the winter season and for two months but in summer the price will increase to up to 10000 SDG/ton (for two months).

Industry

There are many factors dealing with fruits and vegetables processing in Sudan but most of these factories are out of functioning because the grown variety is unsuitable for processing characteristic, financial storage and lack of technical experiences.

9. Import of fruits and vegetables

Import of fruits started in the mid nineties from Egypt, China, Quarter and Lebanon. These are grapes, strawberries, apples, cherries, kiwis and pears.

10. Export of Fruits and Vegetables

In spite of the high potential and diversification of horticultural products, the export of fruits and vegetables is very limited as it contributes around 2% of the total exported food commodities (HS, 2009).

The export business started in the early seventies and the amounts exported are still low (Idris, 2006). Most of the Sudanese vegetables are produced in winter (November-March) which is the best time to fill the seasonal gap demand in European markets for onions, eggplant, sweet pepper, snap-bean, Gallia melon, hot pepper, squash and okra. Fruits with high export potential are mango, banana, grapefruit, dates and lime. Export links with European and Gulf countries is being established e.g. Holland, England, Italy, France, Greece, Saudi Arabia, Qatar, Kuwait, Jordan, Bahrain and United Arab Emirates (Elyas, 2008). Gezira State is the most important state in the export of fruits and vegetables, followed by River Nile and Northern states. Average amounts exported are shown in

Table 4.

Table 4. Average amounts of yearly exported fruits and vegetables.

Crop	Amount (ton)
Onion	185
Tomato	27
Snap-bean	73
Lime	57.1
Mango	305.8
Banana	271.2
Grape fruits	26.4
Melons	727

Source: Sudanese Standardization and Metrology Organization, Ministry of Ministries.

10.1. Factors affecting programs and plans for fruits and vegetables export

1.Small holding fields for export crops and poor cultural practices.

2.The absence of suitable export varieties to compete in international markets.

3.Lack of suitable and well defined technologies for growing fruits and vegetables for export.

10.2. Major Constrains facing the export of fruits and vegetables

(1)Post-harvest practices

- Poor infra-structure and logistics which include inadequate transport system, absence of refrigerated transport, insufficient cold storage, grading and packing facilities.
- Lack of proper knowledge in post-harvest practices by both producers and exporters.
- Complicated custom services.
- Poor airport handling i.e. pallets handling.

(2)Air-freight

Horticultural crops are mainly exported by air. Problems faced are:

- High cost of air-fright 1000-1200 US$ per one ton to Europe.
- Frequent delays in flight schedules.
- Charter flights contracted are not equipped with noise isolation system which is necessary to land in European countries.
- High cost of rented planes.
- High competition with other exporting countries.

(3)Marketing

Technical barriers

- Poor quality of produce as far as post-harvest treatments is concerned.
- Lack of sustainability.
- Poor internal transportation system and processing facilities.
- Poor production and the lack of specialized varieties for export.
- Absence of sanitary certificates required at the other end.
- Unreliable feed back and absence of market information.
- Limited technical marketing expertise.
- Limited marketing organization with resources capable of gathering and disseminating market information.

Financial barriers

- Lack of agricultural finance.
- High production and export risks which limits banks credit and finance.
- High cost of service fees and taxations.
- High cost of the agricultural inputs.
- Poor marketing extension in Sudan.

Constraints and potentialities of the horticulture sector

- Low productivity due to disease and pest problems, lack of certified seeds and availability and high post-harvest losses (50%).
- Irregular production, consumption and prices.
- High temperatures lead to irregular flowering e.g. optimum flowering for mango is 8-15ºC at night. It also increases the rate of ripening and hence relatively short shelf-life.
- High cost of agricultural inputs.
- Availability of proper packaging materials.
- Inadequate cold chain. Preservation of quality requires an unbroken chain from the field to the consumers. No cold stores facilities are available at the centers of production, central markets and airports.
- Weak entrepreneurial skills.
- Inadequate market knowledge and weak marketing channels and mechanisms. No effective market linkages are established.
- Weak management skills in the fields of production planning, production practices and organization of harvesting at the correct maturity for fresh consumption, processing and export.
- Lack of extension services and weak technology dissemination mechanism for the application of proper post-harvest operations developed by Food Research Center (FRC) and the Agricultural Research Corporation (ARC).
- Availability and access to credit and finance.

Potentialities

- Horticultural crops are products of high demand locally and in overseas markets.

- There are great potentialities to expand production areas e.g. in Kassala, Northern and Gedarif states.
- There is a winter window of opportunity in export markets (during December – March) due to a long growing season (winter and summer seasons) e.g. in Kassala State.
- The value added through processing is high and hence its impact on GDP will be appreciable.
- Availability of experienced laborers and accessibility to cheap water and irrigation infrastructure.
- Availability of an extensive range of institutions and skills in the public sector e.g. Ministry of Agriculture and Forestry, ARC, FRC and universities.

Conclusion

In conclusion, there are slight increases in fruits and vegetables production and limited amounts exported. Thus there is an urgent need for a total revision of Sudan's horticultural policies with the objective of increased production and better qualities of produce. Agricultural scheme should be adopted and financed, taxation policies should be revised to make the sector competitive in international markets.

Recommendations

- Investment in infrastructure and post-harvest technologies. The government of Sudan adopted a series of macro economic policies to promote the investment environment in the field of agriculture. These policies insures no discrimination between the invested fund by reason of being local or foreign, or by reason of its being a public, private, co-operative or joint sector. Investment act gives privileges such as:
  1. Exemption from the business profit tax, for a period not exceeding five years.
  2. Exemption may not exceed 70% of the custom duties and any other taxes.
  3. Production and consumption duties.
  4. Allotment of necessary land at an encouraging price for the project to competent bodies.
- Improvement of productivity per feddan through the introduction of new high quality breeds and by development of the local hybrid seed production.
- Development of integrated horticulture supply chain.
- Promoting an enabling environment through:
  1. Increasing awareness and market information.
  2. Making credit more affordable.
  3. Improving technology dissemination and extension services.
  4. Creation of an effective market linkage.
- Establishment of a regional training centre run by public and private sectors e.g. in Kassala State in order to link R & D's, extension departments and farmers.
- Supporting R & D institutions financially and technically.

- Application of proper post-harvest operations developing by FRC to reduce losses, increase productivity and up-grade qualities.
- Economical utilization of existing vegetables and fruit factories' capacities i.e. Kassala Canning and Onion Dehydration factories to increase the revenue from the added value. The objective should be exporting processed products instead of raw materials. International companies and firms are encouraged to invest in this sector.

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Some Horticultural Post Harvest Aspects in Sudan with Special Focus to Banana

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Introduction

Sudan is one of the largest countries in Africa. It lies in the hart of Africa content between long. 21-38 E and lat. 4-22 N. Sudan enjoys wide variety of climates ranging from desert in the north, tropical and subtropical in the middle and equatorial in the south. It has been blessed with abundant water recourses from rivers, rain, and under ground water beside huge areas of fertile soil.

The country has got reasonable infra-structure including railways, paved roads connecting the regional capitals and the main production areas with the federal capital and the national seaport at. Also there are international airports, well established network of telecommunication.

In Sudan there is about 84 millions hectares available for cultivation of which about 17 million are actually cultivated.

The vegetables cultivated areas is about 273154.14hectares with total production of 3.4 M tons with average productivity of 12.5 ton/ ha. The fruit cultivated area is about 158864.85 ha with total production of 1.9 m tons with average productivity of 14.4 ton/ ha. Sudan has the capability of producing fruits and vegetables, ornamental plants, spices, and medicinal plants allover the year. Production for export is highly specialized for being trace naturally and free of chemical residues.

Problems Facing Fruits and Vegetables Export:

1. High cost of agricultural inputs.
2. Cultural practices still need a lot of extension, training, and applied research.
3. Improper harvest time and process.
4. Lack of precooling.
5. Bad access roads conditions leads to great losses and reduces the quality of the produce.
6. Insufficient centers for grading sizing and backing.
7. High cost of backing materials.
8. High cost of air transportation. For example, A ton of produce to Europe will cost more than one thousand $, also the trips are not regular.
9. Marketing problems which include:
   (a) No strict adherence to market specifications
   (b) Lack of regulatory and sustainability of export produces

(c) Non sufficient market information
(d) Weak government finance.
(e) Weak processing for surplus.

Solutions

1. Production cost must be reduced by reducing cost of inputs, charges, and irrigation cost.
2. Provision of necessary finance.
3. Improvement of production quantity and quality by:
   a. Training of farmers to improve their work in the field and post-harvest practices and create awareness.
   b. Strengthening and support of research and extension services.
   c. Implementation of suitable technical packages.
   d. Weed and pest control.
   e. Delegation of information to exporters.
   f. Improvement of nursery services.
4. Strengthening and support of necessary infrastructures for export.
5. Provision of market information.
6. Encourage investment in agricultural industry.
7. Diversification of exportable crops and creation of new markets through efficient market survey and study and recognition of market size.
8. Regulation and organization of air transport.
9. Introduction of sea transport which is cheaper.

Exportable and promising horticultural crops include mango, lime, grapefruit, banana, papaya, melon, onion, green beans, sweet and hot pepper, okra, potato, medicinal and aromatic plants.

Banana

The area cultivated with banana in Sudan is estimated at 41340 feddans with a total production of 400000-500000 tons per year. About 87% 0f total production comes from three states, namely Sinnar, Blue Nile, and Kassala. Within the three states, Sinnar state comes on the top (in fact the top of the country) as 73% of total production of banana in the country comes from this state. Then come Blue Nile state with 8%, and Kassala state with 6% of the total production.

In Sudan, there are a lot of factors in favour the production of banana. These factors include availability of fertile soil, suitable climate, experienced farmers, adequate technically qualified personnel in addition to that Sudan is near Gulf market. Almost only dwarf Cavendish variety of banana is produced in the Sudan. More than 95% if not 100% of banana produced in Sinnar and Blue Nile states is transferred to Khartoum state where is it ripened and sold in the local market.

The situation of banana can be discussed with regard to:

A. local market

Although the bananas are generally clean in appearance in the field, the quality presented in the market is poor and a lot of post harvest losses occur which are estimated at 30-40%. The reasons for that are:

1)Condition in the field:

The various cultural practices are not well paid attention, fertilisation is done occasionally. Although the temperature in the production areas (Sinnar, Blue Nile) range from 30-42 Celsius, it did not affect plant growth and development because of the irrigation by flooding which also add to the fertility of the soil. No serious pests and diseases are observed.

2)Harvest:

The farmer has good experience with regard to harvest time but the harvest process is not done properly. The bunches are cut and put over each other in a front of a pile in a place in most cases not shady waiting for truck which in most cases do not come in proper time. There is no any post harvest treatments.

3)Loading and transport:

Worker are not fully aware of right way of loading of trucks which are usually overloaded in addition people normally travel together with the banana on the same track with their luggage kept on the top of the load. The distance between the production areas and Khartoum is a bout 700-900 km. the truck at first has to pass through the bad access roads from the farm before reaching the paved road. Although the main road connecting the production area with Khartoum is paved but it is not in a good condition in many part of it where holes and cracks exist. A long the road there is a lot of tax points where the driver has to stop and pay for traffic taxes or to check his documents. Also drivers are not aware of the load they carry and they take a lot of time resting at service areas. Due to all these fact, the trucks take more than 16 hours before they reach the ripening rooms in Khartoum. During the rainy season the story is different. The truck can not move any more in access roads to farm so the truck wait beside the main paved road. The banana is lifted from the farm by a tractor-trailer to the place of the truck and then the load is transferred to the truck. Several tractor trips are needed for one truckload, which means more handling, more cost and more delay to the produce.

4)Unloading and ripening conditions:

On arrival at the ripening rooms, the handling of the bunches is rough. The bunches are thrown from the truck to a man waiting beside and he in turn throw it to the ground. The common practice in most ripening rooms is to dip the bunches one after another in a barrel of water which is usually not changed even if it becomes dirty. By doing so the fungal spores from banana will accumulate in the water which becomes a source of fungal infection. After unloading the bunches are then weighed and piled on the floor of the room almost up to the roof in this way air circulation will be severely hampered. The ripening rooms are seldom washed or cleaned and when washed on soap or disinfectants are used. As a result the rooms are conducive to growth of micro organisms. Most

if the rooms are cooled by a simple form of coolers and there is no device for regulating the fluctuation of the temperature and humidity.

5)Retail market:

Selling banana by retail is conducted in the central market, super markets and at the roadsides. Also the handling of the fruit in the retail market is bad and in most cases the banana is presented under the sun. The bad quality of banana presented in the retail market is the result of this bad fruit chain, which lack refrigeration.

B. Banana export

In spit of an area of 31340 feddans cultivated with an average production of 400000-500000 tons, only small trail shipments found their way to the export markets. To study the situation of banana export a comparative study was conducted (Imam, 2001) where banana production and export for five years (1993-1997) was compared with the production and export of other three horticultural crops namely mango, Lime and grapefruit for the same period.

By referring to table (1) banana production comes in the second level after mango with a percentage of 25.6%. table (2) shows that banana export comes at the bottom and the amount exported is very low and non-sustainable . Form the table ,the total amount exported during the five years equals only 19.5 tones, which represents only 0.06% of the total amount export of all fruits in the study, which equals 32315.19 tones. If we take the total amount of banana exported during the five years (19.5tones)as percentage of the amount of banana produced during the same years it constitutes only 0.0009% (table 3).from the three table (1, 2 and 3) , it is clear that the problem of banana export is not is not related to production . also the problem is not a lack of market because sudan is next door to gulf area where the market capacity is very large. Table 4 shows that a total amount of 688000 tones of banana is imported in gulf area in one year . total amount of banana exported from sudan in five years (19.5tones) constitute only 0.016% of the amount imported by Saudi Arabia in one year which is equal 125000 tons .

Table 1. Banana production for the period 1993-1997 as compared with other crops.

Year	Crop								
	Quantity produced (1000 tons)					Percentage (%)			
	Mango	Banana	Lime	Grapefruit	Total	Mango	Banana	Lime	Grapefruit
1993	793.2	405	228	121	1493.2	49.5	27.1	15.3	8.1
1994	776	414	234	217	1641	47.3	25.2	14.3	13.2
1995	821.6	436.5	237	224	1719.1	47.8	25.4	13.8	13
1996	870.4	459	240	238	1807.4	48.2	25.4	13.3	13.2
1997	960	486	252	254	1952	49.2	24.9	12.9	13
Total	4167.2	2200.5	1191	1054	8612.7				

Source: Horticulture Sector Administration.

Table 2. Banana expoert for the period 1993-1997 as compared with other crops.

Year	Crop								
	Quantity exported (tons)					Percentage (%)			
	Mango	Lime	Grapefruit	Banana	Total	Mango	Lime	Grapefruit	Banana
1993	5829.9	768.1	37.1	9.5	6644.6	87.7	11.6	0.6	0.1
1994	6528.2	200.3	13.9	10	6752.4	96.7	2.9	0.2	0.1
1995	5458	866	101	0.0	6425	84.9	13.5	1.6	0
1996	5095	114.1	110	0	5319.1	95.8	2.1	2.1	0
1997	5194	137.7	603	0	5934.7	87.5	2.3	10.16	0
Total	28105.1	2086.2	865	19.5					

Source: Sudan Airport quarantine office

Table 3. Banana export as percentage of production.

Year	Banana production (1000tons)	Banana export (tons)	Export percentage (%)
1993	405	9.5	0.002
1994	414	10	0.002
1995	436.5	0.0	0.0
1996	459	0.0	0.0
1997	486	0.0	0.0
Total	2200.5	19.5	0.0009

Table 4. Annual import of banana in Gulf area

Import country	Total amount imported (1000 tons)	Value (million dollars)
Saudi Arabia	125	78
Iran	145	60
kuwait	24	15
Lebanon	26	13
Libya	35	18.75
Syria	53	23.85
Turkey	165	82.5
UAE	60	36
Rest of Gulf	55	33
Total	688	359.5

Source: FAO, 1998.

The problems of banana export are

1. improper harvest methods and bad handling
2. absence of backing houses
3. lack of refrigerated trucks
4. improper mode of transportation
5. insufficient scheduling
6. lack of post-harvest treatment
7. other problems shared with other horticultural corps

Solutions

1. Roads must be improved specially access roads
2. Backing houses must be established
3. Training of farmers for suitable cultural practise
4. Farmers must be trained how to harvest and conduct post harvest handling for such delicate crop
5. Creation of awareness among workers and drivers about the need of care and gentle handling for banana
6. Loading operation must be organized in advance to avoid delays
7. Farmers must be trained to use traveler boxes instead of transporting banana as bunches
8. If the boxes are not affordable by they should but a layer of wood at the middle of the truck so that the load of bunches is separated into two parts to reduce damage of the fruit
9. Other solutions shared with other crops

Efforts to improve banana handling

An improved method of harvest and handling of banana was conducted [imam,2001] and compared with the traditional methods of handling. The improved methods involves careful cutting by two persons, dehanding under water treated with chlorine 100 ppm then dipping in fungicide (TBZ 300 ppm) as a separate treatment. The hands are then backed in traveller boxes ($\mathbf{69 \times 30 \times 25}$ cm). The boxes are then loaded in the truck and transferred to Khartoum for ripening. The result of the study showed that there is a significant difference in the percentage of losses and the grade of fruit. The total losses decreased from 41% to 12.3% and the quality percent raised from 6.6% to 58.1%. This method of dehanding, washing, backing is demonstrated several times in the field in front of the farmers for training purpose.

References

1. Imam, M.A.M. 2001 “Improvement of harvest and handling methods of banana for export purposes”, M.Sc. thesis , Omdurman Islamic University-Khartoum–Sudan (in Arabic)
2. FAO Year Book 1998.

2010 AARDO Workshop on
Technology on Reducing Post-harvest Losses and
Maintaining Quality of Fruits and Vegetables
186-196

Technology on Reducing Post – harvest losses and Maintaining Quality

Abdul Hamid Al Imam
Syria

Abstract

The Syrian working paper includes three chapters. The first Chapter contains general information about the Syrian Arab Republic (where the site - the border - the most important cities – population). It also includes the agriculture in Syria (where importance - the distribution of land use - agricultural settlement zones – the important agricultural products, value of agricultural commodities for commercial exchange). The second chapter contains a presentation of post-harvest techniques (Harvest - Pre cooling - Quality Control in the field – Packaging – Transport) and the best practices to be followed to reduce the loss and maintain the quality of fruits and vegetables.

The third Chapter contains the recommendations for marketing chain and post-harvest techniques, these recommendations are at the macro level, at the farm level and the retailer level.

Worksheet also includes many forms and important illustrations in point.

Introduction

1. General Informations about Syrian Arab Republic

Syrian Arab Republic is republic in southwestern Asia continent, bounded on the north by Turkey, on the east by Iraq, on the south by Jordan and on the west by Lebanon and the Mediterranean Sea. Syria is divided into fourteen governorates, these governorates are divided into a total of sixty districts.

The capital Damascus is the largest city in Syria, it is One of the oldest cities in the world, where many of the landmarks and cultural. The most important cities in Syria are:

- Aleppo in northern Syria, the second largest city, it is also a major industrial and cultural center.
- Latakia along with Tartus are Syria's main ports on the Mediterranean sea.
- Homs in central of Syria and Deir -Zor on the Euphrates river in eastern Syria.

The total population of S.A.R. inside the country at the end of 2008 is (19880000).

Fig. 1. Shows the location of Syria in the world.

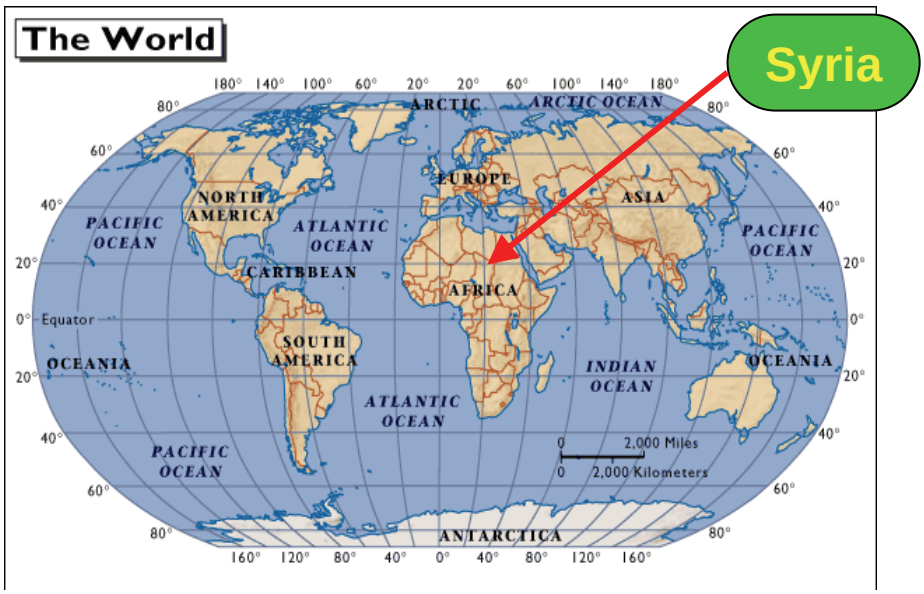


Fig. 1. Syria's position in the world.

And Fig.1. Shows the map of Syria and its borders.

Fig. 2. Map of Syria and its borders.

2. The Agriculture In Syria

A special situation is going to the agricultural sector in Syria within the other economic sectors which compose the national economy, and that is visible because the food is given to citizen regularity, the raw material is available to the industry normaly, the commercial balance is raised and the foreign coinage is available to finance the requirements of others economic sectors. During the past years the Syrian government adopted many structural Adjustment programs; this reflects the increasing growth rate of agricultural export due to increase in agricultural production, specially for the products that have Relative Advantage. The area of Syria is (18517971) ha distributed as in table 1:

Table 1. Land use in Syria for 2008.

Total Area	Cultivable Land	Uncultivable Land	Steppe and Pastures	Forestes
18517971	6023792	3683404	8231974	578801

Fig. 3 shows the land use in Syria for 2008.

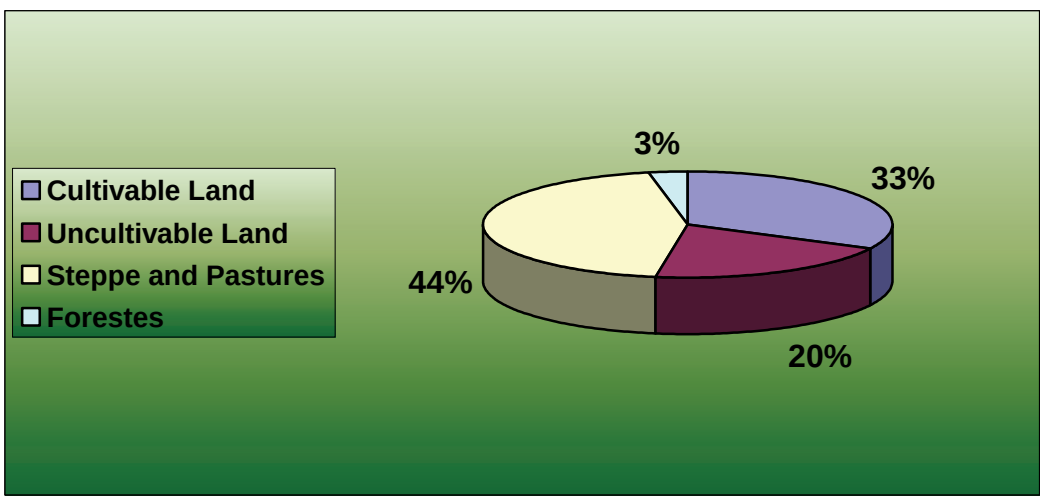


Fig. 3. Land use in Syria for 2008.

Syria is divided into five agricultural settlement zones according to the amount annual rainfall as follows :

First settlement Zone

A zone with annual rainfall over 350 mm, It is divided into two areas:

- The area of annual rainfall rate over 600 mm, Where rain field crops could be successfully planted.

- The area of annual rainfall rate between 350 - 600 mm, and not less than 300 mm, during the 2/3 of the relevant year, it is possible to get two seasons every three years and its main crops are: Wheat, Legumes and Summer Crops, The area of this zone is 2701000 ha, That forms 14.6 % of the country area.

Second settlement Zone

A zone with annual rainfall 250 - 350 mm, and not less than 250 mm. during 2/3 of the relevant year, i.e., it is possible to get two barley seasons each three years, and could be planted beside barley, wheat, legumes and summer crops, the area of this zone is 2475000 ha, that forms 13.3 % of the country area .

Third settlement Zone

A zone with annual rainfall 250 mm, and not less than this figure during the half of the relevant years i.e. it is possible to get one to two Seasons each three years. Its main crops is barley, legumes could be planted, the area of this zone is 1303000 ha, that forms 7.1% the country area.

Fourth settlement Zone (Marginal)

A zone with annual rainfall rate between 200 - 250 mm, not less that 200 mm during the half of the relevant years, lt is good just for barley or for permanent grazing crops, the area of this Zone is 1830000 ha, that forms 9.9% of the country area.

Fifth settlement Zone (Desert and steppe)

This area covers the rest of the country land and it is not suitable for rain field planting, the area of this zone is 10,209,000 ha, that forms 55.1% of the country area.

Fig. 4. Shows distribution of agricultural settlement zones in Syria.

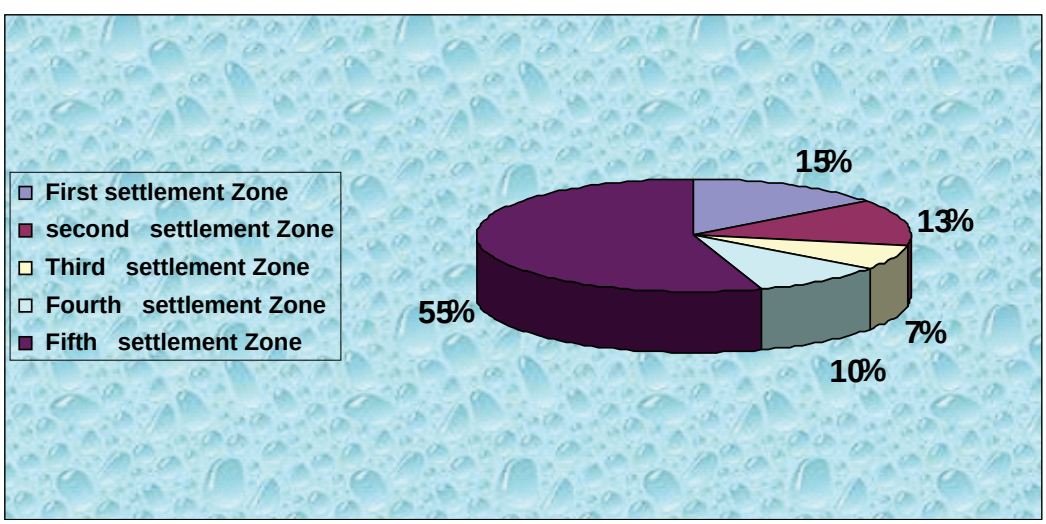


Fig. 4. Distribution of agricultural settlement zones in Syria.

Despite climatic handicaps Syria produces a wide variety of crops, some in sufficient quantity for export. The major crops are cereals, primarily wheat and barley; cotton, grapes, olives, citrus, other fruits such as (Apples, pears, apricots, cherries, peaches, plums, figs, pomegranates, pistachios ..) and vegetables (Potatoes, tomatoes, cucumbers, cabbage, lettuce …) .

The agricultural production value for 2008 by fixed prices amounted / 351511 / million s.p. including / 217068 / million s.p. for plant production value & / 134442 / million s.p. for animal production value. The total value of agricultural commodities for commercial exchange and their percentage to the total exchange of the country in 2007 and 2008 are as in table 2.

Table 2. The total value of agricultural commodities for commercial exchange

Year	2007		2008	
Commercial Exchange	Value/Million s.p	Percentage	Value/Million s.p	Percentage
Import	57442	8.4%	93781	11%
Export	110048	19%	113163	16%

Post - harvest Techniques in Syria and the Mechanism of Improvement

Agricultural sector suffers from many problems that are an obstacle to growth and development, Foremost of these difficulties the problem of agricultural marketing and post – harvest techniques, In addition to technical operations in the field and packing centers and wholesale markets, These Operations include farming practices that must be carried out on farm in order to obtain a good harvest to ensure its ability to compete against a similar product in foreign markets and thus achieve the best profits, These practices begin to determine the appropriate time for harvest and ending with transfer of products to target places, whether the wholesale markets, or sorting and packing centers, or factories, therefore We must know the most important Post - harvest techniques that contribute to maintaining quality of fruit and vegetables.

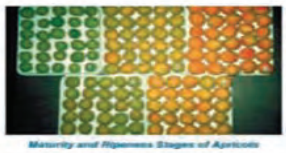
1. Determine the harvest date

Harvest date subjects to many factors including: the specific and clear signs of growth in addition to desires of consumers (size, color and degree of maturity), method of harvest manually or automatically, and nature and type of crop and peak breathing.

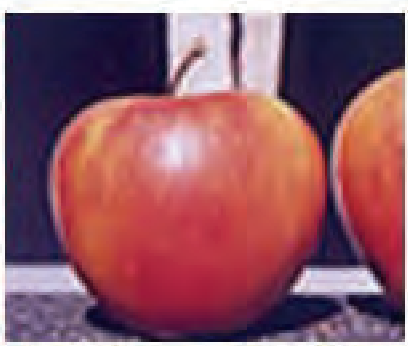
In principle, it is recommended usually harvest in the early hours of day to minimize of temperature field and reduce the costs of cooling units, and should maintain the agricultural products in the shade until they are transferred, It is also recommended to transfer the product as soon as possible.

Photo No. 1 shows stages of maturation in the lemon:

مراحل اكتمال النمو في الليمون



In all cases, harvest date varies by type of fruit. Some farmers pick when the fruitage reach physiological maturity, such as apples, pears and peaches.



Also some crops are picking after their arrival at the final stage of ripening such as strawberries, grapes, cherries, tomatoes, and others.

2. Pre – cooling (Rapid cooling)

Refrigeration is the most important technology to maintain quality of agricultural products, the high temperature is the main reason for deterioration of these products and increase loss.
The most important features of rapid cooling and disposal of temperature field are:

- Reduce of fruit respiration and thus reduce the damage.
- Reduce of transpiration, thus reducing water loss and wilt.
- Reduce of production of ethylene gas and thus delay the maturity and variegated and deterioration of fruit quality.

Note that need for rapid cooling vary from one product to another example:
Grapes - lettuce - strawberries - the flowers should be cooled within a period not more than 3 hours after picking, but Products that are less sensitive to damage such as apples – tomatoes – apricots should be refrigerated within 24 hours.

There are several ways for rapid cooling:

1. Forced air cooling.
2. Hydro cooling.
3. Vacuum cooling.
4. Ice cooling.

3. Quality Control in the field

We must start with application of quality standards for agricultural products in a series of treatments post-harvest and immediately after start with the harvest to reduce mechanical damage or injuries or bruises which are caused by workers, and should also be applied during the collection and mobilization in field. In addition to exclusion of infected fruits and try to initial sort according to color and size, which reduces the effort required in packing centers and reduces costs.

The farmers must use portfolio quality field contains : testing device and measuring the sugar (Refractometer) - device for measuring fruit diameter - Plates for measuring the degree of coloration - A measure of soil acidity - A measure of moisture.

In addition to that the process of mobilization is a very important in series of post-harvest and marketing of vegetables and fruits. It aims to mobilize fruits in boxes of various designs based on crop type, target market.

There are many products that must be mobilized in field because of its sensitivity and to minimize damage during the process of handling , such as grapes and strawberries.
I will show some pictures of mobilization in field and types of boxes:

4. Packaging

The process of packing is the most important stage in series of post - harvest for handling of vegetables and fruits, as the aim of it is contain the fresh product to achieve intact easy unification handling during transport, storage and marketing, in addition to that the correct packing protect the fresh product from mechanical damages which could affect them during handling, such as bruises resulting from the pressure, collision, friction due to vibration.

The packaging system is very effective in promoting and advertising of agricultural products, The systematic boxes that contain slots for ventilation facilitate cooling process of agricultural products.

It is necessary to put labeling on packages include: type, weight or number and country of origin and brand, and in some cases name of farm and exporter.
I will show Some pictures of packages:

62p
36p

don sol
don sol
don sol
Campestrella de Soria
Campestrella de Soria

5. Transport of fresh agricultural products:

Markets of agricultural products and consumption areas are often far from production areas, as well as export markets. This justifies the importance of transport and infrastructure in a series of post-harvest and marketing of agricultural products.

And we must be sure of past practices during transport in terms of packing compaction and temperature control during transport, as well as the movement of air circulation and ventilation.
It should be noted that selection of the optimum means for transport depends on important factors including: value and importance of crop, susceptible to damage, the distance.
There are many methods for transport:

1. Ground transportation in refrigerated trucks.
2. Rail transport.
3. Air transport.

Whatever means of transport we must take into account the following:

1. Protect the product from heat and wind and loss of water content and mechanical damages.
2. Completion of loading and unloading quickly and carefully.
3. Ensure adequate space for ventilation and air circulation.

منظر داخلي لحاوية مبردة — لف حاوية النقل الجوي بمادة عازلة لمنع ارتفاع الحرارة — شاحنة مبردة

المصدر : دليل معاملات ما بعد الحصاد – fao

Recommendations

1. At the macro level:

1. Training farmers for applying post-harvest techniques, and how to comply with the specifications approved in foreign markets.
2. Establishment of companies and associations which are specialized in marketing.
3. Study of foreign markets and target the most important of them.

2. At the farm level:

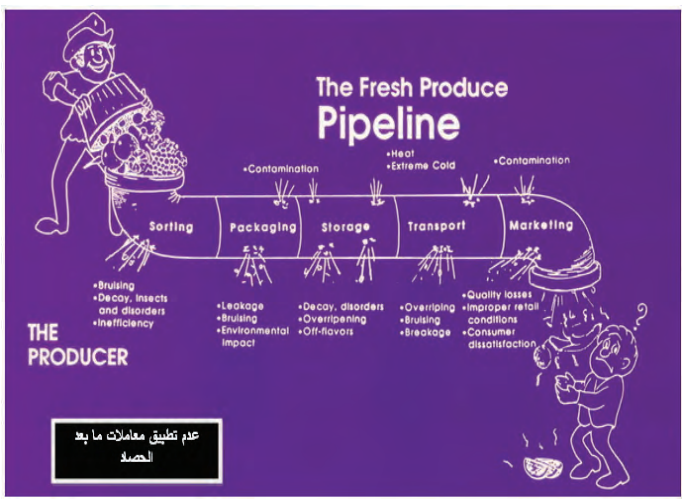
1. Reap the fruits of high quality in appropriate maturity stages, and get rid of unwanted fruits .

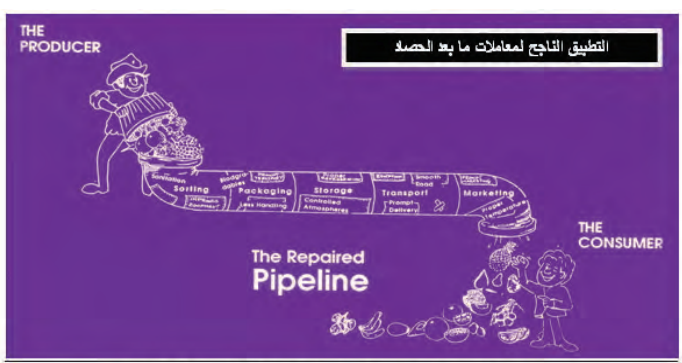
2. Cut through cold hours of day to avoid excess heat.
3. Harvest with technically correct way to reduce of mechanical damage.
4. Mobilization products in a shady spot in field and put the harvested fruits under the shade of trees.
5. Avoid the excess packaging in boxes in order for ventilation.
6. Transport products to market by appropriate chilled means of transport.

3. At the retailer level :

1. Put products in packages of different weights to satisfy desires of consumers.
2. Isolate infected and rotten fruits and get rid of them.

The following painting shows losses and benefits to all dealers in fresh agricultural products, from the producer (farm) passing by sorting, packaging, refrigeration and transport and finally the consumer:





المصدر : VALUE Chains for Fruits - Dr. Errol Hewet - TFNET

2010 AARDO Workshop on
Technology on Reducing Post-harvest Losses and
Maintaining Quality of Fruits and Vegetables
197-204

Post-harvest Losses of Fruits and Vegetables in Zambia

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Abstract

In Zambia, fruits and vegetables play a major role in the diets of most low income households. They are also a good source of essential vitamins and minerals and indeed the source of livelihood. The production and processing of fruits are labour intensive and affected by the challenge of lack of adequate water supply. A lot of people are involved in the marketing and trading of fruits to earn income. Fruits, especially indigenous species are well adapted and can ensure household food security during periods of natural disasters such as droughts. However, the challenge is the high post-harvest losses incurred due to climatic conditions and handling of the produce before consumption. This paper gives an overview of the fruit and vegetables production situation in Zambia. It will also analyse challenges faced in avoiding post-harvest losses and maintaining quality.

Introduction

The post-harvest sector includes all points in the value chain from production in the field to the food being placed on a plate for consumption. Postharvest activities include ; harvesting, handling, storage, processing, packaging, transportation and marketing of the produce are a major problem in the post-harvest chain. They can be caused by a wide variety of factors, ranging from growing conditions to handling at retail level. Not only are losses clearly a waste of food, but they also represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources such as water. Post-harvest losses for horticultural produce are, however, difficult to measure. In some cases everything harvested by a farmer may end up being sold to consumers. In others, losses or waste may be considerable. Occasionally, losses may be 100%, for example when there is a price collapse and it would cost the farmer more to harvest and market the produce than to plough it back into the ground. Use of average loss figures is thus often misleading. There can be losses in quality, as measured both by the price obtained and the nutritional value, as well as in quantity.

Quality of Vegetables and Fruits

In maintaining quality of vegetables and fruits, attention has to be given to:

- Market demand for the products to be grown; he must know the market and the buyers

- Cultivation
- Harvesting and field handling
- Packing or packaging
- Transport
- Market handling; possibly storage or refrigeration
- Sales to consumers, wholesalers or agents
- Perishability of the produce.

Vegetable and Fruit Production in Zambia

The smallholder horticulture sector in Zambia is relatively underdeveloped with few farmers specialising in fruit or vegetable production. Horticultural production is usually a secondary activity producing food for home consumption with surplus for sale usually locally or in nearby towns. The main vegetable crops produced by smallholders are tomatoes, onions, water melons and brassicas (cabbage, rape), Chinese cabbage, amaranth, carrots, cleome, corchorus, cucumber, egg plants, French beans, edible gourds, lettuce, okra, onions, peas, hot pepper (paprika and green pepper), pumpkins. On the other hand, common fruits grown include, mango in the Western and Eastern provinces respectively, pineapples are grown in large quantities in North-western province, oranges, lemons and guavas grown on a small scale country wide.

The fruit and vegetable production in Zambia is mainly of exortic or foreign origin. However, in most rural areas, indigenous or wild fruits are harvested for local consumption and sale in the nearby urban centres. Most farmers regard horticultural production as a secondary activity coming towards the end of the rain season and producing crops for home consumption with a surplus for sale. They usually have limited access to credit for inputs and have major problems getting their produce to markets because of limited transport and poor roads. They rely mostly on family labour and use simple implements like hoes and animal drawn ploughs.

Production of fresh vegetables and fruits for export has increased in recent years. Medium scale and large commercial (both corporate and individual) farmers have invested in all-year round irrigated production of horticultural products as well as fresh flowers. There has been a marked increase in the export of horticultural products, especially with the expansion in number of out-grower schemes. Specialty vegetables include baby corn, mangetout, fine beans, sugar snaps, baby carrots, chillies, patti pans, okra and green asparagus (ZEGA, 2002).

The Role of Women in Post Harvest Losses

In Africa south of the Sahara, the labour of women is more important in all parts of the food production than the labour of men (Fresco, 1986). They must provide the agricultural labour needed in every phase of the food cycle to guarantee the family's nutrition. At the same time, they cannot neglect their other tasks of food preparation, child care, fetching water and fuelwood, washing, housecleaning and looking after the small animals (Presvelou, 1986). Besides these tasks

women also generate income, which is often more than half of the total Household income (Due, 1985; and Fresco, 1986). Thus in many ways women play an important role in the food supply of Households: through their productive labour, their decisions on production, consumption and division of food and through their income, this can contribute to buy food.

The Times newspaper, 2005 reported that, farmers could easily embark on successful banana plantations if they were to follow the techniques concerning the production of the fruit. In fact the demand for banana consumption in Zambia is so high such that producers have not satisfied. Therefore, this calls for more farmers to participate in the production of the fruit in order to satisfy the demand and also earn an income. Like for many other fruits, the main challenge faced is the short life of bananas. Technology is limited to having them harvested before they are ready and within a short period before reaching to the market. Further, open air and road side trading of the commodity makes the weather favourable for quick ripening beyond which they lose the quality and flavour, reducing the market value.

The Importance of Post-harvest losses in Zambia

Time and money are required to cultivate food products, and unless the farmer is providing food only for his own household, he automatically becomes part of the market economy: he must sell his produce, he must recover his costs, and he must make a profit. Estimates of the post-harvest losses of food grains in the developing world from mishandling, spoilage and pest infestation are put at 25 percent; this means that one-quarter of what is produced never reaches the consumer for whom it was grown, and the effort and money required to produce it are lost-forever. Fruit, vegetables and root crops are much less hardy and are mostly quickly perishable, and if care is not taken in their harvesting, handling and transport, they will soon decay and become unfit for human consumption. Estimates of production losses in developing countries are hard to judge, but some authorities put losses of sweet potatoes, plantain, tomatoes, bananas and citrus fruit sometimes as high as 50 percent, or half of what is grown. Reduction in this wastage, particularly if it can economically be avoided, would be of great significance to growers and consumers alike.

Potential of Zambian Fruit and Vegetable Production

Zambian fruits have a high potential to be processed into juices, jams and other assorted drink types if only appropriate technology could be adopted. Though many of these products have some commercial value in their unprocessed forms and usually find their way into urban markets, their potential as industrial raw products is largely unexploited. Little work has been done towards their improvement, domestication or conservation. Some of the fruit species may be endangered making their conservation a matter of urgency. Small-scale horticulturists in Masaiti District on the Copperbelt Province of Zambia appealed to the Government and business companies to partner with the farmers to market their produce locally and abroad. Lack of market usually increases cases of post-harvest losses of the produce. Zambia had a potential of yielding up to 31,700 to

61,200 kilogrammes per hectare under intensive commercial growing conditions. The production output of banana yields of 6,800 to 15,900kg/ha and 22,700 to 34,00kg/ha could be considered good. However, in Zambia, the average yield of bananas for most of small-scale farmers is 12,000kg/ha and this yield may be as a result of disease attacks.

Challenges in Fruit and Vegetable Production

Fruits and vegetables are living parts of plant and contain 65 to 95 percent water. When food and water reserves are exhausted, produce dies and decays. Anything that increases the rate at which a product's food and water reserves are used up increases the likelihood of losses. Increases in normal physiological changes can be caused by high temperature, low atmospheric humidity and physical injury. Such injury often results from careless handling, causing internal bruising, splitting and skin breaks, thus rapidly increasing water loss.

Transport

Transportation is a big and often the most important factor in the marketing of fresh produce in Zambia. Ideally, transport would take produce from the grower directly to the consumer, as in many developing countries. In more complex marketing systems (those serving towns, cities or distant countries)' the cost of transport contributes significantly to the price paid by the consumer, and sometimes exceeds the value of the raw product. Losses directly attributed to transport conditions can be high. Further, the road system is poor and becomes impassable especially during the rainy season from most of the rural areas to urban centres. This is a big challenge and increases post-harvest losses. The goal of every person concerned with transport should be that the produce be kept in the best possible condition during transport and that the haulage of produce be quick and efficient. To this end, produce should be properly packaged and properly loaded on a suitable vehicle.

Losses Caused by Transportation

The damage and loss incurred during non-refrigerated transport are caused primarily by mechanical damage and by overheating.

Mechanical damage: Damage of this type occurs for many reasons, including:

careless handling of packed produce during loading and unloading; vibration (shaking) of the vehicle, especially on bad roads; fast driving and poor condition of the vehicle; poor stowage, which allows packages in transit to sway; the stow may collapse packages stacked too high; the movement of produce within a package increases in relation to its height in the stack.

Overheating: This can occur not only from external sources but also from heat generated by the produce within the package itself. Overheating promotes natural breakdown and decay, and increases the rate of water loss from produce.

Marketing

Factors affecting post-harvest food losses of perishables vary widely from place to place and become more and more complex as systems of marketing become more complex. In Zambia for instance, a farmer who is growing fruits for his family's consumption probably doesn't mind if his produce has a few blemishes and bruises. But if producing for a market at any distance from his own locality, however, he and his workers, if he has any, must have a different attitude if he hopes to get the best money return on his work.

It is more important for the grower to change the attitude of himself and his workers toward reducing post-harvest losses than it is for him to think that buying fancy packaging will automatically solve his problems and improve his income. Reduction of post-harvest losses reduces cost of production, trade and distribution, lowers the price for the consumer and increases the farmer’s income. In preserving the quality of the produce reaching the final market, the whole marketing chain from the producer to the final consumer must be examined for any weakness. The reduction of Post harvest losses makes significant contributions, minimizing the postharvest losses have been made through research on the physiological changes in the product after storage, new long life varieties, suitable the product after storage, new long life varieties, suitable cultivation circumstances, optimum harvesting indices, recommended storage recommendations, precooling refrigerated transport and careful handling.

Diseases and Pests

All living material is subject to attack by parasites. Fresh produce can become infected before or after harvest by diseases widespread in the air, soil and water. Some diseases are able to penetrate the unbroken skin of produce; others require an injury in order to cause infection. Damage so produced is probably the major cause of loss of fresh produce.

The influences of all three causes are strongly affected by the various stages of post-harvest operations, discussed below. Furthermore, they all have great effect on the marketability of the produce and the price paid for it.

Traditional Post- harvest losses

Traditional post-harvest technologies which make use of very simple techniques are predominant in low income countries Zambia inclusive. These technologies which are, in general, applied by subsistence farmers are very rudimentary and labour-intensive. They are focused on handling household food requirements and any surplus is sold in local market outlets.

There is limited post harvest technology being practiced for fruits in Zambia. However, traditionally, vegetable preservation is done by many people in rural agricultural areas by boiling and drying in the harvest period. Vegetables loses reduced by drying include, paprika and chilis on

commercial purposes. It is important to note that this technology is limited to commercial farmers.

In Zambia farmers have poor control or influence over the markets like the major urban markets where middlemen have significant influence and push prices down. Various attempts have been made to increase returns to the farmer and to improve access to markets. Several out-grower schemes linking smallholders to high value markets appear to be functioning successfully but most of these are located around Lusaka. These markets however tend to demand high levels of quality and consistency of supply that most smallholders are unable to meet.

Another problem faced by smallholders is that they usually have limited access to water for dry season cropping. This is a major limitation to increased productivity and extension of the growing season because rainfall is only from November to April and in agro-ecological region 1 the total is less than 800 mm. Farmers are compelled to produce vegetables under rain-fed conditions which are conducive to high levels of pests and diseases. The main production period for vegetables is therefore after the rainfall season up to the time when ground water reserves dry up (from April to about August). This problem can be overcome by the development of irrigation facilities; however credit facilities and other initiatives to encourage purchase of low cost pumps are not readily available to most smallholders. This means that dry season production is confined to perennial water sources or wetlands (dambos). Some smallholder growers however have tried to specialise in vegetable production due to the higher profit levels and they tend to be more responsive to extension advice and market demands and they are more willing to invest their own resources (e.g. they buy pumps with their own money).

Recommendations for Future Research on Post Harvest Loss Reduction Focus should

1. Not only be limited to storage conditions but also to market requirements, breeding and cultivating circumstances.
2. Focus on treatments to arrest deterioration, harvesting at correct maturity, pre-cooling to reduce field air, care during sorting, packaging, transportation are also determinant post-harvest factors.
3. Consider a significant change to the current seasonal production system to having year round vegetable production and it is important to have good training and extension support so the farmers adapt to the new production system.
4. Water harvesting technology should be encouraged among small scale farmers to enhance irrigation and continuous production.
5. Extension services should be extended further to small scale farmers for enhanced disease prevention.
6. Small scale farmers should form cooperatives to have collective access to meet big markets such as supermarkets

Conclusion

Technology to reduce post-harvest losses of fruits and vegetables should be encouraged through the use of local technology which in most cases is cheaper and sustainable. Small scale farmers should have access to extension services to learn about measures to reduce post harvest losses. As stated earlier, fruits and vegetables can greatly contribute to food security and empowerment of vulnerable sectors of society like women and the rural farmers.

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Group Discussion

Group Discussion

Session Chair: Dr. Fu-Wen Liu

Three topics will be covered in group discussion for the three groups as following:

1. Challenges and opportunities in the improvement on post-harvest handling technologies to reduce losses and maintain quality of fruits and vegetables.
2. Priorities and strategies in overcoming the challenges in the development of post-harvest technologies.
3. Priorities and strategies in future research, development and application of post-harvest technologies.

Group I is responsible to make a solid conclusion on topic 1, Group II is responsible for topic 2, and Group III for topic 3.

Report of Group I

Topic: Challenges and opportunities in the improvement on post –harvest handling technologies to reduce losses and maintain quality of fruits and vegetables

Adviser: Dr. Fu-Wen Liu

Member:

Name	Country	Note
Dr. Mohammad Aqeel Faraj Al-Awaida	Jordan	Chair person
Dr.(Mrs.) Hind Abd Elmonem Elbashir	Sudan	Secretary
Mr. Mohammad Mosaddeque Ali	Bangladesh	
Mr. Min Chi Hsu	R.O. China (Taiwan)	
Mr. Rashid Khalfan Surur Al-Shekaili	Oman	
Mr. Adrian Phiri	Zambia	
Ms. Chia-Hui Tang	R.O. China (Taiwan)	
Ms. Shu-Wen Chiang	R.O. China (Taiwan)	

1. Losses in fruits and vegetables

There are huge losses that occur in fruits and vegetables due to poor post-harvest practices. Losses in Afro-Asian countries usually range between 5%-35% in the local market but for the export market it is about 15%-45%.

2. Major Challenges

(1) Poor Marketing System

Generally there are no formal marketing institutions dealing with fruits and vegetables. In most of the countries farmers and producers deal as individuals and in very informal way for marketing their commodities. The trade lacks exhibition sheds, loading and unloading platforms, cold stores and trucks loading equipments. Therefore the producers sell their products at very low prices especially perishable vegetables.

The performance of the horticultural crops marketing system is irregular in terms of prices, profits and cost of production and is unsustainable hence it is a traditional and ineffective system. In most of the countries no effective market linkages have been established and also weak management skills in sorting, processing, and selling cause huge losses prior to fresh consumption as well as for export.

Co operative marketing system and rapid transportation of the produce to the wholesale market can minimize the post-harvest losses. Avoiding the middle man's interest farmers can get more values for their cash crops.

(2)Absence of appropriate policies, infrastructure

The government of most of the countries has no proper or appropriate policy for maintaining post-harvest losses. Poor infra-structure and logistics which include inadequate transport system, absence of refrigerated transport, insufficient cold storage, lack of grading and packing facilities are mainly responsible for high post-harvest loses. Complicated custom services and poor handling also cause losses. So government should formulate appropriate policy to support every stakeholder involved in post-harvest management process chain. Government should also develop requisite infrastructure like; roads, power, cold storage etc…. to facilitate in minimizing post-harvest losses.

(3)Lack of Capacity in Postharvest Management

Limited number of well trained researchers and technical staff also the lack of proper knowledge in post-harvest practices by both producers and exporters.

(4) No significant emphasis on research and development.

Poor allotment for research and development is one of the great concerns for PHM –MQFV. For minimizing losses and maintaining quality of fruits continues research and development is a must. Without R&D no improved technology or performance can be achieved. Sufficient allotments can encourage the scientists and research people to perform well and find out the way for improving PHL and MQFV.

(5) Climate change

Changing in climatic conditions is affecting production in terms of both quality and quantity of fruits and vegetables. Adverse climatic conditions such as extreme temperatures, drought and

rainfall hamper productivity which ultimately leads to poor yielding. Awareness building and adaptation technique can minimize this kind of losses. It needs to be addressed globally.

3. Opportunities in Post Harvest Handling Technologies

(1) Increasing huge demand for fresh fruits and vegetables for local consumption as well as for export market is a great opportunity for PHL and MQFV..

(2) Comparative advantages of different countries to explore by joint collaboration in the different field of Land, Water and Labour Technology etc should be utilized by joint collaboration. So that every country can get benefit by optimum of their resources. Every country should avail this opportunity by continual efforts increasing productivity and maintaining the quality of fruits and vegetables.

(3) As the convergent has not enough resources parivet sector come forward to invest in the sector to change the situation. For e.i. establishing the processing industry which can play a great role in value addition, Private Sector Investment in processing industry for employment generation as well as value addition, in establishing cold storage, fruit-vegetable shade in village areas etc.

(4) Sharing of knowledge regarding post-harvest technology within member countries and also with other countries.

(5) Collaboration with large international agencies and institutions like FAO, World Bank, Asian Development Bank etc.

(6) NGOs which are engaged in income generating activities with farmers and women in rural areas can be involved in the process of post-harvest management to minimize losses.

Report of Group II

Topic: Priorities and strategies in overcoming the challenges in the development of post harvest technologies

Adviser: Dr. Syed Mohammed Ilyas

Member:

Name	Country	Note
Mr. Sita Ram Jat	India	Chair person
Mrs. Roop Soodha Munbodh	Mauritius	Secretary
Ms. Yi-Tan Fang	R.O. China (Taiwan)	
Mr. Ramir Mendoza Apaga	Philippines	
Mr. Mohamed Abdalla Mohamed Imam	Sudan	
Ms. Ya-Ling Chang	R.O. China (Taiwan)	
Mr. Chie-Hsiang Liu	R.O. China (Taiwan)	

Development and application of new technologies in the field of post harvest management is, of necessity to reduce the losses in fruits and vegetables after harvest. This sector must continue to develop and use the best technologies available all over the world and it should be able to serve the agriculture sector in most competitive way globally. We must recognize that the business world and the professional world are becoming more “action and results” oriented, and less “domain or territory” oriented.

The challenges of the Euro-Retailer Produce for Good Agricultural Practice benchmarks in areas of traceability, records keeping, timely availability of high quality planting material, appropriate soils, efficient input use, selective plant protection, timely harvest & effective post harvest management, hygiene, Safety and environment issues are suitably dealt with. There is increasing concern about the environmental effects and safety of chemical pesticides and fungicides all over the world. Integrated pest management with emphasis on biological control of pre- and post harvest insects and diseases has been one of the most extensively studied alternatives and appears to be a viable technology. Huge commercial successes in biological control are still rare. Currently, the main hurdle facing widespread use of post harvest bio-control strategies is the decreasing efficacy and lack of consistency found when these methodologies are applied as standalone treatments under commercial conditions.

Advantage of using inhibitors of ethylene action to protect the tissue against both endogenous and exogenous ethylene has been established. Development and commercial availability of water-soluble inhibitors will expand the potential use of the inhibitors in PHM.

Appropriate post harvest handling can minimize moisture loss, slow down respiration rate and inhibit the development of decay causing pathogens. Temperature is the most important determinant of fresh produce deterioration rate. An important supplement to proper temperature and relative humidity management is the use of controlled (CA) or modified (MA) atmosphere. Knowledge about physiological factors affecting shelf life and applications of modified atmosphere packaging (MAP) and related technology in prolonging shelf life of fresh fruits and vegetables, films available for packaging fresh produce, classification of horticultural commodities according to respiration and ethylene production rates and MAP potential for benefit for whole and fresh-cut fruits and vegetables are not available. The use of nano-technology in developing the packaging films has great potential.

Growth in demand has led to increased marketing of fresh fruits and vegetables in fresh-cut products form. The physical and mechanical damages caused during preparation increases respiration and ethylene production, which leads to increase in other biochemical reactions responsible for changes in colour, flavour, texture and nutritional quality such as vitamin loss as well as being subjected to bacterial and fungal infestation. Thus keeping freshness in fresh-cut horticultural produce and finally the maturity, quality and marketing of fruits and vegetables also needs further studies.

Maturity at harvest is one of the main factors determining the quality of a product. Post harvest technologies deal with separation, sampling, sizing, sorting, grading and marketing operations. These post harvest handling procedures are most important as they may either protect the quality or ruin much that was achieved up to this stage.

A one or two days delay in marketing can make the difference between profit and loss. Therefore, need to develop maturity indices, quality standards according to country wise and cultivars/ variety wise so as to sensitize the producers at governmental or cooperative levels for assuring uniform quality, positively impacting the marketing systems.

The losses at post production level being huge need to be minimised considerably by using appropriate technology, equipment and practices. There is a need to develop suitable protocols for optimising the operations in view of reducing delays in transactions at all levels. The governments must provide support to transfer the knowledge and technologies by using different modes of media.

The group has considered all the relevant issues and proposes the following action plan:

A. Harvesting:

Challenge	Existing practice	Areas of Improvement/new technology
Lack of proper timing harvest	Practised as their indigenous knowledge	Training & Sensitization for optimum harvest time/stage of produce and Further research on determination of optimum harvest time/stage.
Poor quality of produce.	Use of traditional unscientific practices	1. Sensitization of farmers on quality production through mass media methods. 2. Appropriate dosage of pesticides prior to harvest(MRL)
Improper techniques/ tools to harvest the produce	Manual harvesting mostly by hand tools & use of energy inefficient techniques	1. Specialized tools/or machinery 2. Development/application of electronic nose /machine vision for determination of optimum stage.
Global gap principles	Growers not aware about the principles	Training & demonstration on Global Gap principles.

B. Handling and Transport of fruits and vegetables:

Challenge	Existing practice	Areas of Improvement/new technology
Improper handling	Harvested produce mostly kept exposed	Special efforts to create awareness/ popularization of safe harvest methods
Inadequate on farm facilities	Operations carried out by manually mostly by untrained workers	Sensitization on comparative advantages & development/application of cheaper mechanical/ electronic sorters, graders, equip.
Poor cool/ cold chain	In existence or fragmented cold chain	Development of suitable protocols and modern machinery on subsidised rates

Improper loading & unloading.	Careless loading and unloading, over stacking &mixed loads	1. Awareness on safe produce handling. 2. Development/ popularization of easily workable loading/ unloading implements
Poor transport network	Unreliable train ,sea and air transport	Development of produce specific protocols and suitable machinery for transport system.

C. Packaging/Storage

Challenge	Existing practice	Areas of Improvement/new technology
Inadequate pack house & cold storage facilities	Poorly designed pack house & mostly single commodity based cold storages	1. Strong government support (policy, technical and financial) 2. Introduction & promotion of multi-commodity & multi-chamber storages 3. Dev. of protocols & adoption of C.A. and M.A storage
Poor packing materials	Mainly locally available packing materials	1. Use of produce specific packing materials 2. Promotion of packing line concept.
Energy inefficient machinery based storages	Old, outdated, ill-maintained evaporative cooling/refrigeration system.	1. Development/introduction of energy efficient, low cost refrigeration systems. 2. R&D on application of renewable energy sources in cooling / refrigeration
Lack of parameters	Unscientific storage by non trained workers	Awareness about and application of produce specific storage protocols.

D. Marketing

Challenge	Existing technology/practice	Areas of Improvement/new technology
Seasonal nature of produce	Irregular/ fragmented supply of produce, seasonal gluts	Research and development on high yielding varieties with longer shelf life and Staggered production schedules.
Lack of market intelligence	No systematic demand and supply information on fruits and vegetables	1. ICT based marketing system 2. Regular forecasts on the market demand and prices using mass media.
Multiplicity of intermediaries	Lack of transparency in marketing and trade	Promotion of modern wholesale / terminal markets having electronic auction along with hub & spoke marketing system.
Poor market infrastructure	Disorganised and unhygienic marketing system	1.Government policies/support for creating modern marketing infrastructure. 2.Establishment of commodity boards.
Lack of traceability	Absence of labelling on produce pack	Introduction of concept of traceability and conforming to quality & safety standards of domestic and export markets

Priorities in overcoming the challenges in the development of post harvest technologies:

1. Reduction of post harvest losses
2. Training of farmers in quality and safety of produce
3. Development of post harvest and marketing infrastructure
4. Formulation of post harvest management enabling policies
5. Incentives and financial support from farmers to growers for following GAP and achieving high quality of raw material
6. Strengthening the infrastructure for cool/cold chain and dedicated road, rail and water shipment of perishable produce
7. Establishment of pesticide residue testing laboratories at strategic locations

Strategies in overcoming the challenges in the development of post harvest technologies:

1. Initiation of farmer supporting policies & programmes by the governments and creation of modern cold chain & modern markets infrastructure near the production catchments
2. Liberal government support for R&D and extension on post harvest management and also promoting peoples action towards achieving higher value addition at each node of post harvest value chain
3. Development and commercial availability of water-soluble inhibitors reducing spoilage in ethylene producing fruits
4. Technology/ knowledge about physiological factors affecting shelf life of fresh produce, quality of films used for packaging in MA storage, classification of horticultural commodities according to respiration and ethylene production rates and nano-technology for developing the packaging films.
5. R&D for keeping freshness in fresh-cut fruits & vegetables, maturity standards according to the country's need and marketing of fruits and vegetables in efficient way.
6. Sensitization/ training of farmers in the quality and safety standards & practices through application of mass media.
7. Development and promotion of intensified use of proper harvesting tools & practices.
8. Establishment of packing houses with the facilities of sorting, grading, waxing and packaging concept such that all the major production catchments are covered.
9. Development and popularization of minimal processing and their appropriate marketing.
10. Develop novel value added products from ethnic fruits & vegetable for niche market and export as health foods/ green foods etc.
11. Encouragement of cooperative/corporate / PPP for promoting contract farming of high quality fruits & vegetables and to minimise the multiple intermediaries between grower and processor;
12. Promotion of private & corporate sectors in sharing investment in the establishment of efficient marketing systems of fruits and vegetables;
13. Development of suitable strategies for use of post harvest bio-control treatments under commercial conditions.
14. Incentives/ financial support including subsidies to growers for using efficient cleaning, grading, sorting etc equipments for effecting appropriate post harvest management.

Report of Group III

Topic: Priorities and strategies in future research, development and application of postharvest technologies

Adviser: Dr. Chao-Chia Huang

Member:

Name	Country	Note
Dr. (Mrs.) Perlita Aquino Nuevo	Philippines	Chair person
Mr. Md. Feroz Hossain	Bangladesh	Secretary
Mrs. Matida Dabo	Gambia	
Mr. Severino Kinge Manene	Kenya	
Mr. Abdul Hamid Al Imam	Syria	
Ms. Nien-Tzu Wang	R.O. China (Taiwan)	
Mr. Shih-Huang Huang	R.O. China (Taiwan)	

General objective:

To reduce post harvest losses and address the issues of quality and food safety of fruits and vegetables.

	Priority	Strategy
Research	Innovation of new technologies and useful tools needed in respective countries or area including the following:	Asking funds for research from international organization, government, and industry, etc. Exchange of experience and technology among groups (farmers, countries, etc) Exchange of information
	1.Preharvest factors -Water -Organically produced -Nutrient management -Pesticide management -Plant hormones -Fruit thinning -Bagging	1.Preharvest factors -Water -Organically produced -Nutrient management -Pesticide management -Plant hormones -Fruit thinning -Kinds of bagging materials
	2.Harvesting -Maturity determination of fruits and vegetables -Method of harvesting	2.Harvesting -Maturity indices of fruits and vegetables -Improvement of harvesting tools and techniques
	3.Sorting -Sorting by size, color, TSS (quality)	3.Sorting

	Priority	Strategy
	4.Precooling	4.Precooling
	5.Grading and standardization	5.Grading and standardization
	6.Cleaning	6.Cleaning
	7.Ripening -Climacteric and non-climacteric	7.Ripening -Climacteric and non-climacteric
	8. Disease and insect control	8.Disease and insect control
	9.Packaging	9.Packaging -Low cost packaging
	10.Storage	10.Storage -Low cost storage -Refrigeration
	11.Food safety - Intact and fresh-cuts fruits and vegetables	11.Food safety -Good agricultural practices -Chemical residue analysis
Development	Establishment and adaptation of new technologies with good results from research on the items mentioned above particularly on: -Harvesting tools and methods -Precooling -Use of appropriate containers -Transport system -Postharvest laboratories, facilities, infrastructures -Food safety - Intact and fresh-cuts fruits and vegetables	Pilot project for commercial use Experience and technology exchange among groups (farmers, countries, etc) Collaboration of researchers with the industry Asking for funds from international organizations, government, and industry etc. for the development of technology
Application	Extension of established technologies -HACCP -Traceability -GAP, GMP -Awareness of postharvest handling and food safety among the players (extension workers, farmers, handlers, service providers)	Training of postharvest experts Workshops Demonstration Experience and technology exchange among groups (farmers, countries, etc) Asking for funds for extension from international organization, government, and industry etc. Asking for information

Conclusion: If we are able to satisfy and address the issues which we have enumerated, the problem of huge postharvest losses would be minimized resulting in

Conclusion of Group Discussion

From the discussion, we know that postharvest losses is severe or very severe in each country. The distribution must be improved for consumer demand and also increase the profit of farmers. To improve the situation, we need technology. There is lack of postharvest experts and we need them to do research and extension. They should develop technologies which would be implemented. Road condition is poor and there is a need to improve transport. To improve transport, we need national support. We need sufficient funding and manpower.

In some countries, there are more land resources, others have advanced technologies and others have a supply of labor. It is putting these together so that there is complementation. Assistance from the international organizations and the private sector could be tapped. We need improvement and in order to improve, we have to exchange knowledge.

In the future, we must strengthen the collaboration with each other and extend more to other countries. In so doing, we will lower the postharvest wastage by 5%. In effect, the consumers and growers will be benefited.

Closing Remarks

Closing Ceremony Address

Dr. Junne-Jih Chen
Director General
Taiwan Agricultural Research Institute

Good morning, Honorable Mr. Sanjeeb Kumar Behera, Dr. Fu-Wen Liu and Dr. S. M. Ilyas, Distinguished Participants from Member Countries of AARDO, Ladies and Gentlemen:

The workshop is finally come to an end today. I would like to use this opportunity to congratulate on all the participants for your successfully completing the entire program. Later on you will be presented a certificate for this achievement. I have no doubt that you all have a productive learning from the lectures delivered by resource speakers, from the sharing of country reports given by your pal delegates, and from the activities of field trip and group discussion. I hope that the knowledge and experience you gained from the workshop may feedback in some way to your work as well as agricultural production of your country.

Secondly, I believe that you have established a very good friendship among yourselves during the period of this workshop. I wish you all value this precious friendship and the common memory you share together here in Taiwan. When you go back to your home country, do not forget to keep contact with new friends you make here. Contact each other often for exchanging knowledge and technologies on post-harvest handling, or at least, send a mail to say hello once in a while.

I would like to once again express my sincere gratitude to AARDO and COA for their fully supports to this workshop, to resource speakers and Dr. Fu-Wen Liu for the kind contribution help to mobilize the session. Without your warmly participations and co-operation, this workshop could not be so great and extremely successful.

Finally, I would like to say thanks to my colleagues, you spent your valuable time even in the weekends in preparing and serving the workshop. Ladies and gentlemen, please join me to give them a big thanks and hands.

Bon Voyage! I wish you all have a safe and pleasant trip back to your home.

Thank you.

Conceding Remarks

Dr. Sanjeeb Kumar Behera
Head of Research Division
Afro-Asian Rural Development Organization

Respected Dr. Junne-Jih Chen, Director General, Taiwan Agricultural Research Institute, Distinguished Resource Persons of the Workshop, Participants from AARDO Member Countries, Co-ordinates of the Workshop Dr. Huang and His Team Members, the Future Agricultural Scientists of Taiwan, Who are Attending this Workshop as Observer, Ladies and Gentlemen:

Thank You is a too small expression for you all and as I do not have any other better substitute, I began this concluding remarks with a big thanks to our host, TARI and its Director General for all that you have done for us- for AARDO and its participants of the workshop. We are really highly impressed with your hospitality. You provide us an excellent platform for discussion and sharing of ideas. On behalf of the Organization and the participants, I extend my sincere thanks to TARI, its dedicated team members and the Council of Agriculture for organizing this workshop.

The resource persons of the workshop exposed the participants to the various techniques adopted in Taiwan, India and elsewhere to reduce the post harvest losses. They made our participants involved so much that the discussion was not just confined to the four wall of the workshop room. I noticed discussion on the topic even in the bus and dinner table. On behalf of the Secretary General of AARDO, I extend my sincere thanks to our learned resource persons for their valuable contribution for the successful completion of this workshop.

My thanks is also due to the AARDO member countries and its nodal ministries, who responded our request and allow their senior officials to be here for the workshop. I also extend my sincere thanks to all distinguished participants of the workshop for their contribution to the workshop and I hope that they have learned something new in this island country. I know, every thing can not go smooth but we, i.e. AARDO and TARI made all our efforts to make you comfortable. However, if we have failed somewhere, kindly excuse us. I wish you all a safe return journey back home.

Finally, I once again thanks all those, who have worked for the successful completion of the workshop.

Thanks you for kind attention.

Program Schedule

Date	Time	Activities
Sun, Oct.03		**Arrival of the participants**
Mon, Oct.04	08:50-09:20	**Registration**
	09:20-10:00	**Opening session** • Opening remarks by Dr. Junne-Jin Chen, Director-General, TARI • Welcome address by Dr. Sanjeeb Kumar Behera, Head of Research Division, AARDO • Self-Introduction by participants • Group photo
	10:00-10:20	Coffee break
	10:30-11:20	Presentation and discussion of resource paper I: **"An Overview of Postharvest Biology and Technology of Fruits and Vegetables"** by Dr. Chun-Ta Wu, Assistant Professor of Horticulture Department, National Taiwan University, ROC. Moderated by Associate Professor Tsu-Tsuen Wang
	11:20-12:10	Presentation and discussion of resource paper II: **"Application of Postharvest Technologies forVegetable Crops in Taiwan"** by Dr. Tsu-Tsuen Wang, Associate Professor of Horticulture Department, National Taiwan University, ROC. Moderated by Assistant Professor Chun-Ta Wu
	12:10-13:10	Lunch break
	13:10-14:00	Presentation and discussion of resource paper III: **"Application of Postharvest Technologies for Fruit Crops in Taiwan"** by Huey-Ling Lin, Associate Professor of Horticulture Department, National Chung Hsing University, ROC. Moderated by Associate Professor Tsu-Tsuen Wang
	14:10-14:50	**Presentation of country papers**(**Bangladesh,** 2 participants) Moderated by Associate Professor Tsu-Tsuen Wang
	14:50-15:20	Coffee break
	15:20-16:00	**Presentation of country papers** (**R. O. China**, 2 participants) Moderated by Assistant Professor Chun-Ta Wu

Date	Time	Activities
	16:00-17:00	**Briefing of TARI**
	18:00-20:30	**Welcome Reception at the Splendor-Taichung hosted by COA, ROC**
Tus, Oct.05	09:00-09:50	Presentation and discussion of resource paper IV: **"Development and Application of Citrus Storage Technologies with Concurrent Consideration of Fruit Quality Preservation, Energy Use, and Costs.**" by Dr. Fu-Wen Liu, Professor Emeritus, Cornell University, USA. Moderated by Dr. S.M. Ilyas
	09:50-10:40	Presentation and discussion of resource paper V: **"Best Practices for efficient Post-harvest Management of Fruits and Vegetables for Higher Value Addition and Profitability"** by Dr. S.M. Ilyas, Director, Distance Education Cell, National Institute of Rural Development, India Moderated by Dr. Chao Chia Huang, associate researcher, TARI.
	10:40-11:00	Coffee break
	11:00-12:00	**Presentation of country papers**(**India, Jordan, Kenya,** 3 participants) Moderated by Dr. Chao Chia Huang, TARI.
	12:00-13:00	Lunch break
	13:00-13:40	**Presentation of country papers** (**Mauritius, Gambia, 2** participants Moderated by Dr. S.M. Ilyas
	13:40-14:20	**Presentation of country papers** (**Oman. Philippines**, 2 participants) Moderated by Professor Fu-Wen Liu
	14:20-15:00	Coffee break
	15:00:16:40	**Visit Soil Museum and Plant Germplasm Division** in TARI
Wed, Oct. 06	09:00-09:50	Presentation and discussion of resource paper VI: **"Residue Control by Using Rapid Bioassay of Pesticide Residues (RBPR) for Market Inspection and Farm Education"** by Ms.Ching-Hua Kao, Researcher, TARI, ROC, Moderated by Dr. S.M. Ilyas
	09:50-10:50	**Presentation of country papers**(**Philippines, Sudan,** 3 participants)

Date	Time	Activities
		Moderated by Dr. S.M. Ilyas,
	10:50-11:10	Coffee break
	11:10-11:50	**Presentation of country papers** (**Syria, Zambia,** 2 participants) Moderated by Ms. Ching-Hua Kao
	11:50-13:00	Lunch break
	13:00-13:20	Preparation of group discussion (grouping)
	13:20-15:10	**Group discussion** At Training Center, TARI. Moderated by Professor Fu-Wen Liu, Dr. S.M. Ilyas, and Dr. Chao Chia Huan,
	15:10-15:30	Coffee break
	15:30-17:30	**Group discussion** (continued)
Thu, Oct. 07	09:30	Field trip
	09:30-10:00	Proceed to Taichung Industrial Park, Taichung
	10:00-11:00	**Visit Unispace Cold Storage Co., LTD,** Taichung
	11:00-12:00	Proceed to Visit HanKuan Fruit & Vegetables Production Cooperative, Silou, Yunlin Hsien
	12:00-13:00	Lunch break
	13:00-14:30	**Visit HanKuan Fruit & Vegetables Production Cooperative**, Silou
	14:30-14:40	Proceed to the next site
	14:40-16:30	**Visit Siluo Fruit and Vegetables Wholesale Market**
	17:30-19:30	**Farewell dinner at** E-LU restaurant Wufeng**, hosted by TARI**
Fri, Oct. 08	08:50-09:50	**Summing-up of group discussion**, Moderated by Professor Fu-Wen Liu, Dr. S.M. Ilyas, and Dr. Chao-Chia Huang
	10:00-11:00	**Concluding session**, Oral presentation group by each group, Moderated by Professor Fu-Wen Liu

Date	Time	Activities
	11:00-11:20	Coffee break
	11:20-12:00	**Closing ceremony** • Closing remarks by Dr. Junne-Jin Chen, Director-General, TARI • Awarding the certificate by Dr. Sanjeeb Kumar Behera, Head of Research Division, AARDO
	12:00-13:30	Lunch break
	14:30-	Visit National Museum of Natural Science
Sat, Oct. 09		Return of participants and resource persons to respective countries

Appendix II: List of Participants

Information of resource speakers, AARDO officials, participants, and observers

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